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# TEXTILE RESEARCH JOURNAL

VOLUME XVI | September, 1946 | NUMBER 9

PUBLICATION OF

TEXTILE RESEARCH INSTITUTE, INC.

AND

THE TEXTILE FOUNDATION

*Editorial Office:* 10 East 40th Street, New York 16, N. Y.

# TEXTILE RESEARCH JOURNAL

VOL. XVI, No. 9 September, 1946


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TEXTILE RESEARCH JOURNAL, published monthly at Prince and Lemon Streets, Lancaster, Pa., is devoted to the interest of research in textile and allied industries. It is the official publication of Textile Research Institute, Inc., and the Textile Foundation.

Manuscripts and communications should be sent to the editorial offices, 10 East 40th Street, New York 16, N. Y.

Subscription rates: General—$10.00 per annum; additional for postage, 50 cents to Canada, $1.00 to all other countries. Special—$5.00 per annum for United States and Canadian students, teachers, educational institutions, public libraries, governmental libraries and departments, plus 50 cents for postage to Canada. Single copies, $1.00 each.

Entered as second-class matter, April 27, 1945, at the postoffice at Lancaster, Pa., under the Act of August 24, 1912.



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TEXTILE RESEARCH JOURNAL

VOL. XVI, No. 9 September, 1946

# Wear-Resistance of Apparel Textiles, I

## Tests of Military Fabrics on Quartermaster Combat Course

**Ernest R. Kaswell**

*Fabric Research Laboratories, Inc., Boston*

*Portion of a research program on the* Wear Resistance of Apparel Textiles, *sponsored by the Office of The Quartermaster General and the National Research Council, and conducted by the Textile Division of the Massachusetts Institute of Technology, Cambridge, and the Fabric Research Laboratories, Inc., Boston, Massachusetts.*

*Part II, "Laboratory Evaluation of Military Fabrics and Correlation with Combat Course Tests," will appear in a later issue.*

### I. Introduction

An intensive survey of the literature [1] concerning abrasion studies over the past twenty years indicates a wealth of description of abrasion and wear-testing machines designed for use in the laboratory to predict the utility and life of fabrics under service conditions. However, the literature is less extensive in proposing methods of evaluating damage done to fabrics by laboratory abrasion devices. It recognizes a need for controlled service testing and then correlation with laboratory test methods. While the need is recognized, few controlled, quantitative service tests have been made, for obvious reasons. Neither personnel, time, nor facilities have been available for conducting such a complete service test. More important, there has been no "proving ground" of constant, reproducible, and truly duplicative conditions on which to conduct a service test. Hence, no correlation with laboratory tests could be made.

The few attempts at correlations have consisted of testing fabrics in the laboratory, predicting their rank in service wear, and attempting qualitatively to learn whether service wear bore out the laboratory predictions.

Because it was found that the technical laboratory could not predict with accuracy how materials would wear under service conditions, the Combat Course at Camp Lee, Virginia, an infiltration course used to test military clothing and equipage under simulated battle conditions, was constructed by the Quartermaster Corps.

The Textile Division at the Massachusetts Institute of Technology and the Fabric Research Laboratories, Inc., were called upon by the Quartermaster

Corps, through the offices of the National Research Council, jointly to conduct a research investigation, the express purpose of which was to determine to what extent the Combat Course and the laboratory could be correlated.

It was not the primary purpose of this investigation to design a new abrasion machine which would duplicate service wear. Numerous types of abrasion machines are now available, many of which have not been considered satisfactory for the reason that they have never been given the study necessary to insure proper use and proper interpretation of abrasive wear produced thereon. It is felt that it is not necessary that the laboratory abrasion machine *actually reproduce* service wear. If wear produced by the abrasion machine can be correlated with service wear, then the machine can predict the serviceability of a fabric, *provided the results are interpreted correctly.*

The results of this investigation, together with information obtained from other research programs [2] (on the relationship between the inherent elastic properties of fibers and laboratory abrasion-resistance tests), indicate that laboratory methods can now, with reasonable accuracy, predict the serviceability of *fabrics* (in contrast to manufactured uniforms) with a minimum of effort and time compared with the length and complexity of a Combat Course test.

However, the Combat Course accomplishes much more than to enable the evaluation of the wear-resistance of fabrics. It makes it possible to judge clothing design and construction, utility of equipage, and it aids in solving problems pertaining to the soldier's comfort and convenience. It is doubtful that laboratory techniques could ever solve such problems.

## II. Results and Discussion

This investigation is concerned with the wear-resistance of apparel textiles tested on the Combat Course and with the methods of correlating Combat Course results with abrasion-resistance as determined in the textile laboratory upon conventional abrasion-testing machines.

Three cotton fabrics were intensively studied: (1) 8.2-ounce twill, (2) 9-ounce sateen, (3) 9.3-ounce herringbone twill.

A method of evaluating Combat Course wear-resistance was developed, and this was used to test the three fabrics chosen for study. The method may be used for evaluating any fabric on the Combat Course.

Fifteen uniforms consisting of a jacket and a pair of trousers were prepared from each fabric for the Combat Course test. All garments were made with warp yarns running lengthwise. The twill and herringbone were prepared face outward; the sateen was prepared with the back side outward. Each soldier taking part in the test had one uniform of each fabric, in which he made fifteen traversals of the course. At the end of each traversal the garments were inspected and all damages were recorded.

Preliminary study of fabrics subjected to the Combat Course showed the following fundamental types of damage: (1) wear areas: (*a*) mild, (*b*) medium, (*c*) severe; (2) holes; (3) holes in wear; (4) tears. A tear is considered to be a special type of hole.

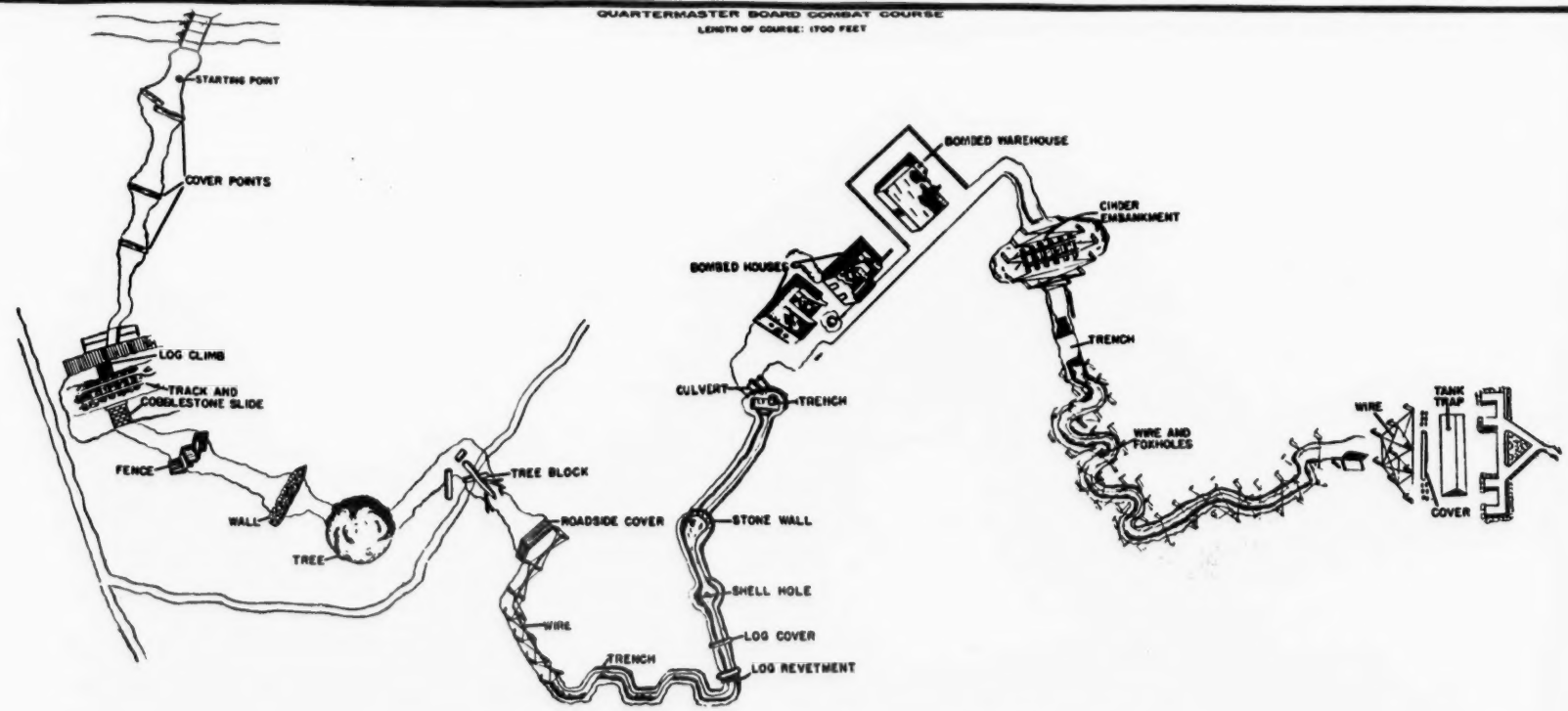
In each instance, the amount of damage is calculated as the area of a rectangle of length and width equal to the maximum and minimum diameter of the damaged area.

By summing areas of the same damage class, the net surface damage ($S$) in square inches for each class is recorded at each cycle. A graph of ($S$) versus cycles is plotted. From such a graph the "destructive index" is calculated. To state that an end-point alone expressed in Combat Course cycles to produce any selected degree of destruction is a valid criterion of wear-resistance is to neglect the importance of rate of destruction. Rate of destruction is essentially the measure of the changing condition of the garment as it proceeds to destruction as a result of abrasion. The destructive index is a number which indicates the rate of damage to any garment at any cycle, the garment's entire past history being taken into account. The lower the destructive index (D.I.), the better the garment.

D.I.'s for each damage class for each fabric were calculated at each cycle. A combined D.I. for all damage classes was calculated by weighting net surface damage ($S$) for each damage class by its percent reduction in warp tensile strength, summing the weighted net surface damages, and calculating a D.I. thereon.

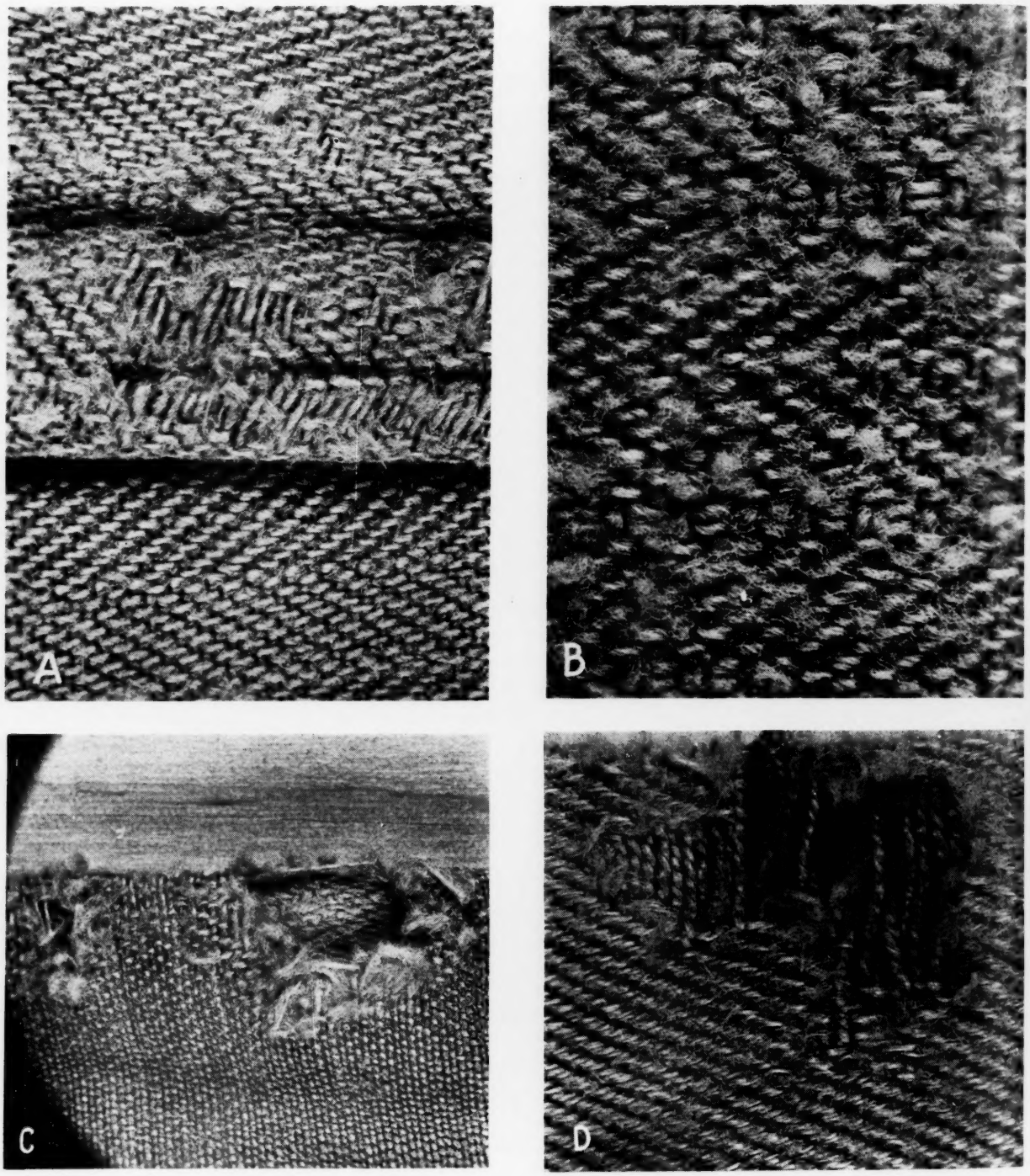
Combat Course D.I.'s show that

(1) The sateen wears out slowest and is therefore best; (2) the herringbone twill (hereafter in this report designated as H.B.T.) wears out 1.8 times faster than the sateen and is next best; (3) the twill wears out 2.1 times faster than the sateen and




GRAPH IV–1. *Quartermaster Board combat course. North is to the left.*

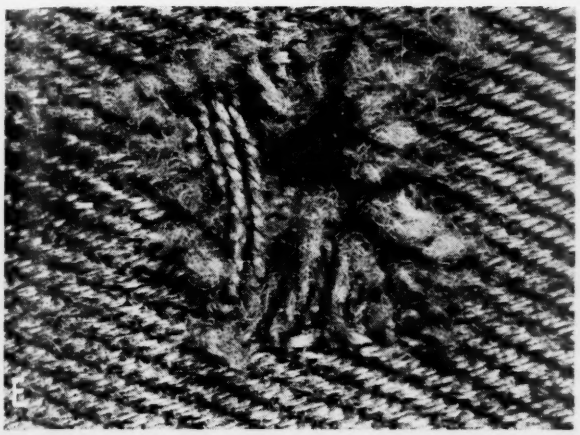
| OBSTACLE | PRINCIPAL EFFECTS ON GARMENTS |
|---|---|
| *Cover points* | *Impact producing strain and abrasion at knees, elbows, and body front.* |
| *Log climb* | *Over-all strain.* |
| *Track and cobblestone slide* | *Over-all abrasion on front.* |
| *Fence, Wall, Tree* | *Impact producing strain and abrasion at knees, elbows, and body front.* |
| *Tree block* | *Abrasion at crotch, over-all strain.* |
| *Roadside cover* | *Impact producing strain and abrasion at knees, elbows, and body front.* |
| *Wire* | *Over-all abrasion on front.* |
| *Trench* | *Abrasion at knees and elbows.* |
| *Log revetment* | *Over-all strain.* |
| *Log cover, Shell hole* | *Impact producing strain and abrasion at knees, elbows, and body.* |
| *Stone wall* | *Impact producing strain and abrasion at knees, elbows, and body with further abrasion of front crawling over parapet.* |
| *Trench* | *Impact producing strain and abrasion at knees, elbows, and body.* |
| *Culvert* | *Over-all abrasion on front and sides.* |
| *Bombed houses* | *Over-all abrasion, strain, and snagging.* |
| *Bombed warehouse* | *Over-all strain.* |
| *Cinder embankment* | *Over-all abrasion on front.* |
| *Trench* | *Abrasion at knees, elbows, and sides.* |
| *Wire and foxholes* | *Abrasion at knees and elbows.* |
| *Wire* | *Over-all abrasion on back.* |
| *Cover* | *Over-all strain (rolling over log).* |
| *Tank trap* | *Over-all abrasion on front.* |

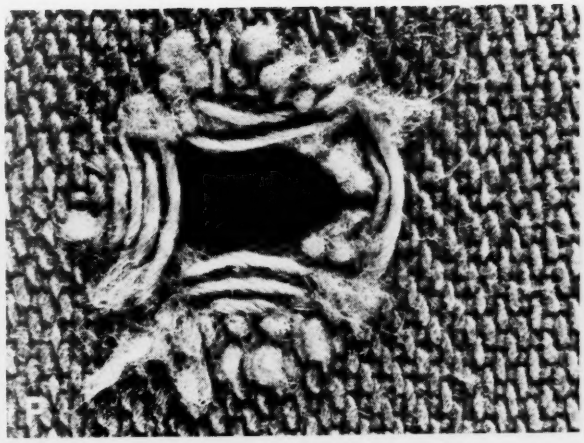


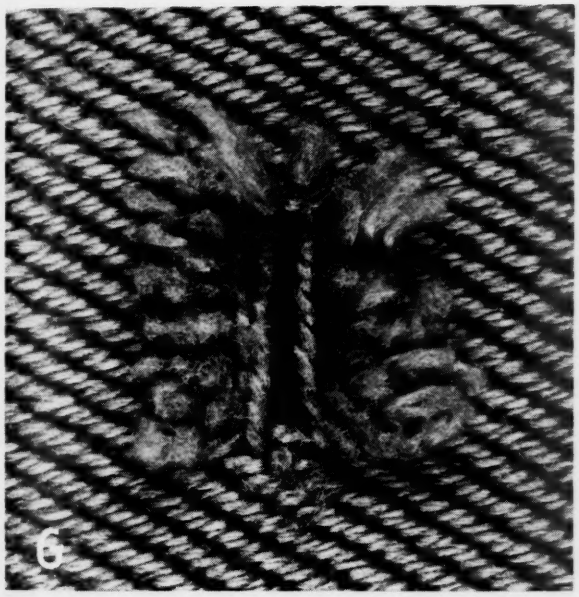

*Photomacrographs IV–2A–I. A and B—Wear areas. C, D, and E—Holes in wear. F and G—Holes. H and I—Tears.*

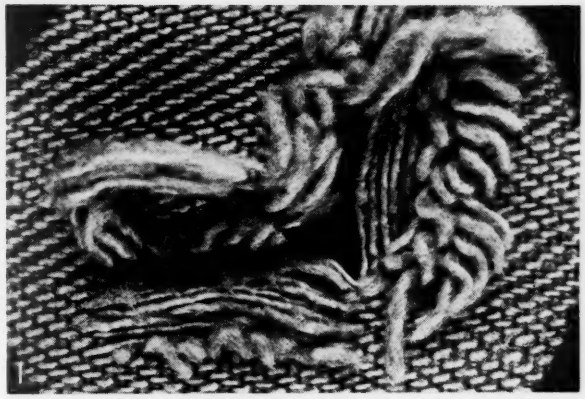
is worst; (4) the twill probably wears out slightly faster than the H.B.T. The difference between them is small compared with differences between twill and sateen, and H.B.T. and sateen. (5) The above conclusions apply to the twill face, H.B.T. face, and sateen back when the warp yarns run longitudinally in the garment.

Two conventional abrasion machines were studied in the laboratory: The M.I.T. unidirectional and the Taber multidirectional. Samples of the three fab-









rics were abraded for varying numbers of cycles and the tensile strengths of the abraded portions were determined. Graphs of percent loss in tensile strength versus abrasion cycles were then plotted for the following abrasion and test directions: (1) abrade warp-test warp, (2) abrade filling-test warp, (3) abrade filling-test filling, (4) abrade warp-test filling. Such graphs were plotted for each fabric, face and back, for each of the two machines. Areas under the percent-loss-in-strength-versus-cycles curve are "laboratory destructive indices" (L.D.I.'s) and may be compared with Combat Course D.I. values.

Laboratory results show that both the M.I.T. and Taber machines rank the abrasion-resistances of the fabrics in substantially the same order. The agreement between machines is good. Both show

percent-loss-in-strength-versus-cycles curves of the same mathematical type—namely, $L = a \log C + b$, where $C$ = abrasion cycles, $L$ = percent loss in strength, and $a$ and $b$ = constants. The constants vary, depending upon fabric geometry, abrasion direction, and tensile-test direction. Therefore, no direct relationship between Taber and M.I.T. machines is known at the present time. It cannot be stated that $x$ cycles on the M.I.T. machine are equal to $y$ cycles on the Taber.

Laboratory results show that fabrics abraded in different directions have the same abrasion-resistance rank when tested in a single direction; fabrics abraded in a single direction show inverse abrasion-resistance rank when tested in perpendicular directions. The sateen back when abraded and tested warpwise, and the twill face when abraded and tested fillingwise, are the most abrasion-resisting surfaces.

The inherent abrasion-resistances of the three fabrics are identical, in that they are all made of cotton. Therefore, the differences between the six surfaces are differences of fabric geometry; for example, yarn size, twist, sett, diameter; fabric weave; picks and ends per inch; percent warp or filling yarns on the fabric surface; float length, etc. Such noninherent fiber properties are collectively called the "form factor"; it is form factor which controls the abrasion-resistance of fabrics made from the same fiber.

A fabric surface which has high abrasion-resistance in one abrasion and test direction has poor abrasion-resistance in the opposite abrasion and test direction. What is gained from form factor in one direction is lost in another.

If the six surfaces of three fabrics of equal weight (and of the same fiber) were abraded and tensioned equally in all directions, the combined abrasion-resistances in all the abrasion and tension directions would be equal for the three fabrics. This is borne out substantially in this investigation by summing the L.D.I.'s for the four abrasion and test directions; the results showed no significant difference in abrasion-resistance rank between the six fabric surfaces.

Fabrics have specific abrasion-resistances for specific abrasion and test directions. In order to predict the abrasion-resistance of a fabric under service conditions, the predominant abrasion and tension directions under service conditions must be known.

Photomacrographs of each fabric were prepared to assist in the interpretation of laboratory abrasion results, Combat Course results, and correlation between the two. The figures on pages 416 and 417 represent Combat Course damages.

Analysis of the motion of the men as they traversed the Combat Course led to the conclusion that both the direction of abrasion and the direction of tension were predominantly longitudinal with the man. Since the garments were made with the warp yarns running lengthwise, it was predicted that the best Combat Course fabric would be that which was best able particularly to withstand warpwise abrasion and warpwise tension. The photomacrographs confirm and explain the Combat Course results. The twill- and H.B.T.-face fabrics are warp-flush. Warpwise abrasion during the Combat Course traversal causes severe warp yarn damage, resulting in warp failure under tension. The sateen back is a filling-flush fabric; warp yarns under the same abrasion and tension conditions are protected. Hence warpwise abrasion does little damage and on ensuing warpwise tension the warp yarns are strong enough to resist breakage.

By similar analysis laboratory abrasion-resistances of every fabric surface for every abrasion and test direction may be predicted from photomacrographs. Correlation between photomacrographic prediction, M.I.T., and Taber results is excellent. With certain limitations which must be thoroughly understood, laboratory abrasion-resistance rank may be predicted from photomacrographs.

Although garments tested on the Combat Course are subjected to predominantly warpwise abrasion and tension they are not entirely. Other abrasion and tension directions also affect over-all abrasion-resistance. Combat Course results show the twill face and H.B.T. face to have approximately twice the D.I. of the sateen back. For quantitative correlation, L.D.I.'s should bear this same relation. If abrade warp-test warp L.D.I.'s are compared, twill face/sateen back and H.B.T. face/sateen back ratios are much higher than the required 2 to 1. It is obvious therefore that other abrasion and test directions must be considered (in addition to the abrade warp-test warp) to reduce these ratios until they become equivalent to Combat Course ratios. Conversely, it is seen that on the Combat Course the abrasion and tension direction, while predominantly warpwise, is not entirely so. If it were, the sateen back should have been much more than twice better than the twill face and H.B.T. face.

To arrive at proper ratios, empirically selected percentages of the various laboratory abrasion and test directions must be combined to form a "weighted laboratory destructive index." These empirical percentages cannot be blindly selected; they must be logical combinations. But until the precise magnitude and direction of warp and filling abrasion and the precise magnitude and direction of warp and filling tensions occurring on the Combat Course are known, the percentages must remain empirical.

By experimentation it has been found that if the following percentages of L.D.I.'s for the four abrasion and test directions are calculated and summed, the resulting combined L.D.I.'s for the twill face, sateen back, and H.B.T. face are in approximately the same ratios in the laboratory as they are on the Combat Course:

| | | |
|---|---|---|
| Abrade warp | Test warp | 70% |
| Abrade filling | Test warp | 5% |
| Abrade filling | Test filling | 20% |
| Abrade warp | Test filling | 5% |

The above weighting factors apply only when the warp yarns run longitudinally with the garment. They are not to be construed as the only combination that may be employed. With the present knowledge of Combat Course abrasion and tension directions, no absolute, definite combination can be calculated. The factors are logical from a knowledge of the Combat Course; use of them bears out Combat Course results to a fair degree of accuracy.

Combat Course wear-resistance of textile fabrics may be predicted from laboratory criteria by the following method:

If the warp yarns run longitudinally with the garment, sum the following percentages of laboratory destructive indices:

| | | |
|---|---|---|
| Abrade warp | Test warp | 70% |
| Abrade filling | Test warp | 5% |
| Abrade filling | Test filling | 20% |
| Abrade warp | Test filling | 5% |

If the filling yarns run longitudinally with the garment, sum the following percentages of laboratory destructive indices:

| | | |
|---|---|---|
| Abrade warp | Test warp | 20% |
| Abrade filling | Test warp | 5% |
| Abrade filling | Test filling | 70% |
| Abrade warp | Test filling | 5% |

In both cases, the lower the resulting number the better the abrasion-resistance, and the better the garment will wear on the Combat Course.

By means of the above percentages, the following conclusions and predictions are made concerning the six fabric surfaces studied in this investigation:

If the garment is made with the warp yarns running longitudinally, the sateen back will be best under Combat Course testing. If the garment is made with the filling yarns running longitudinally, the twill face will be best under Combat Course testing.

Weighting values have been empirically determined after extensive study of the Combat Course. They apply to the Combat Course only. It is neither stated nor implied that wear-resistance under any and all service conditions, military and otherwise, may be predicted by use of such weighting values. To predict wear-resistance under service conditions from laboratory methods, a knowledge of abrasion and tension components for such service conditions is necessary. Weighting values may or may not be the same as those empirically found for the Combat Course. The use to which the garment is put would decide whether Combat Course values might judiciously be applied.

## III. Combat Course Testing

### *A. Description of the Combat Course*

The Quartermaster Board Combat Course is a 1,700-foot-long obstacle course designed to simulate battle conditions as closely as possible. It contains fences, road blocks, gravel roads, shell holes, concrete culverts, bombed-out houses, rubble, railroad embankments, trenches, foxholes, tank traps, and the like. Its installations are fixed so that they are substantially immovable. In this way, the Course is essentially the same from day to day (excluding weather variations) and clothing repeatedly tested upon it is subjected to a set of reasonably constant and reproducible conditions. The Course is arranged so that the soldier must pass through the various obstacles chronologically. It is not so rigid that he cannot exercise his individuality and ingenuity in going over the Course with a minimum of effort, provided he traverses each section in a prescribed manner.

Chart IV–1 is a diagram of the Course. It describes each obstacle and its principal effect upon the garment.

*B. Interpretation of Combat Course Data*

After a garment has been subjected to the Combat Course the damages sustained by it must be scored and then, from the score, the garment may be evaluated.

The score records the type and size of damage. The evaluation takes into account the rate at which the score is increasing. Such an "evaluation analysis" results in a numerical index (destructive index) which takes into account the class or type of damage, size of damage, and the cycle (number of traversals of the Course) at which it occurs; hence, it reflects the wear-resistance properties of the garment as a whole. Methods of classifying, scoring, and evaluating Combat Course data are discussed below in detail.

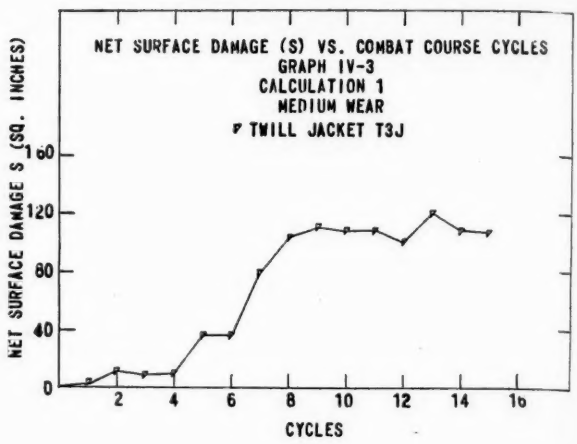
*1. Classification of Damages.* Garments subjected to varying numbers of Combat Course cycles were inspected in the laboratory. Photomacrographs of 125 fabric damages were made and examined in detail. It was found that three fundamental types of damage exist: (*a*) wear areas, (*b*) holes-in-wear areas, and (*c*) holes.

Wear areas are caused by abrasion of such an extent that no hole results. They may be broken down into three categories: mild wear, medium wear, severe wear. A mild wear is one wherein the fabric has been scuffed lightly without any serious damage beyond appearance changes. A medium wear is one wherein yarns have been definitely abraded but not ruptured. A severe wear is one wherein yarns have been abraded to rupture without the actual formation of a perceptible hole.

Holes-in-wear areas are caused by abrasion of an amount such that a hole results. An abraded area surrounds the hole.

Holes are damages caused by such probably fortuitous effects as snags, bursts, punctures, and rips, none of which were preceded by wear and none of which necessarily resulted from wear per se. A tear is considered to be a particular type of hole. Since a large tear makes a garment useless, it was decided to remove the barbs from the barbed wire on the Course, thus keeping tears at a minimum. So few tears resulted that in this investigation they have been entirely neglected.

Photomacrographs IV–2A–I are representative * of 125 pictures taken, and show wears, holes in wear, holes, and tears. The wear pictures do not distinguish between mild, medium, and severe types.

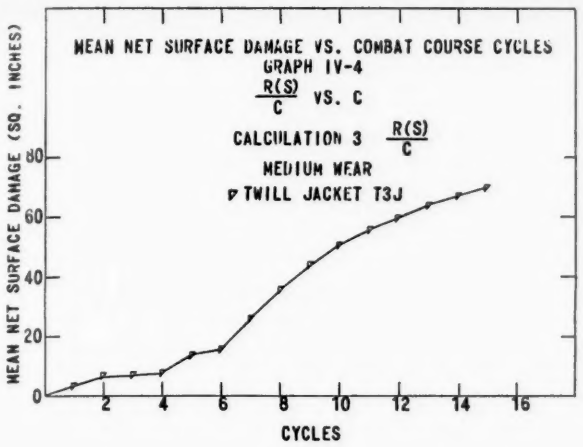


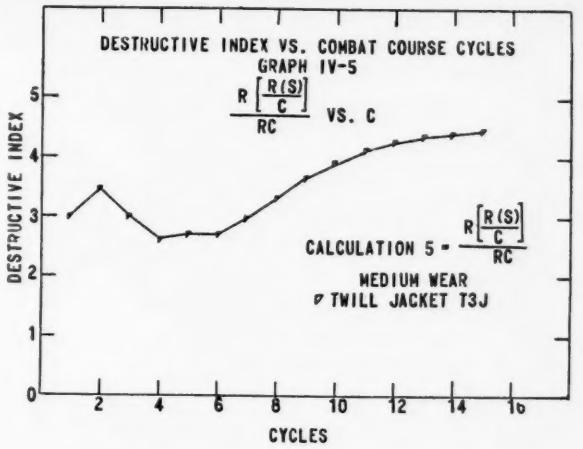

*2. Scoring of Damages.* The Camp Lee Quartermaster Board in conducting a salvage study instituted a scoring system for each classification whereby a damage received a score of 1 to 5, depending upon its maximum diameter. This allowed rapid scoring, which was of prime necessity, but it did not take into account the area of damage, in that a hole 1 inch by $\frac{1}{16}$ inch in diameter (for example) was considered as bad as a hole 1 inch by 1 inch in diameter. Also the damage was graded on a linear basis of 1 to 5, which may or may not have been correct.

In this investigation, in which the problem was to correlate the Combat Course with the laboratory, a more precise yardstick was needed to score damages. It was decided to measure the maximum and minimum diameter of each damage in inches and calculate the area of the circumscribed rectangle. (An ellipse would have been more precise, but the time involved in calculating such areas made this prohibitive.) In this way, the net surface damage ($S$) of any damage class could be calculated at each Combat Course cycle by summing the individual areas. This was more precise and time-consuming than the broad 1-to-5 grouping method. It is certainly not proposed that it be used by the Quartermaster Board for routine work, but it is felt that such a detailed scoring method was necessary to make the correlation requested.

*3. Evaluation of Damage—The Destructive Index Concept.* Graph IV–3 is a representative plot of net surface damage ($S$) versus Combat Course cycles. The area plotted is total damage to the garment, and not merely added damage occurring at a particular cycle. Such a graph is in itself a depiction of the rate at which the garment is being destroyed.

* The graphs, charts, and tables also have been chosen as representative of the complete series.




To state that an end-point alone expressed in Combat Course cycles (or laboratory abrasion cycles) to produce any selected degree of destruction is a valid criterion of wear-resistance is to neglect the importance of rate of destruction. Rate of destruction essentially measures the changing condition of the garment as it proceeds to destruction as a result of abrasion. The path of the $(S)$-versus-cycles curve is therefore of paramount importance.

The number of Combat Course (or laboratory abrasion) cycles required to produce either complete or an arbitrarily chosen extent of destruction is an end-point concept and connotes durability. The path over which destruction proceeds depicts the changing condition of the garment and connotes rate of destruction. The destructive index is a number which indicates the rate of damage to any fabric at any cycle, its past history having been taken into account. This D.I., in that it may be calculated for any selected number of cycles required to produce a given extent of damage, reflects durability. Calculation of D.I.'s at a given Combat Course cycle enables the direct comparison of materials tested on the course at that cycle.

Destructive index is calculated as follows:

(*a*) The net surface damage $(S)$ for mild, medium, severe, hole in wear, etc., at the end of any given cycle is tabulated and plotted (Graph IV–3, Calculation 1).

(*b*) A running sum $R$ of $(S)$ (Calculation 1) is now taken and tabulated; this is called $R(S)$ (Calculation 2). It is done in order to take into account, at any cycle, the path which $(S)$ follows to that cycle, and thus indicates past history. Such an operation because of unit increments in the abscissa (cycles axis) yields the area under the $(S)$-versus-cycles curve.

(c) At each cycle, the running sum $R(S)$ is divided by that cycle, and the resulting data (Calculation 3) are plotted against cycles. The area $R(S)$ is not a sufficient criterion of past history in that two curves of the same shape may have their origins displaced along the cycle axis. This is readily compensated for by dividing by $C$:

$$\text{Calculation 3} = \frac{R(S)}{C}.$$

Graph IV–4 plots $\frac{R(S)}{C}$ versus $C$; the ordinate is mean net surface damage.

(*d*) A running sum of Calculation 3 is now taken to give

$$\text{Calculation 4: } R\left[\frac{R(S)}{C}\right].$$

(*e*) At each cycle, Calculation 4 is divided by a running sum of cycles $R(C)$ to that cycle. This gives the destructive index,

$$\text{Calculation 5: } \frac{R\left[\frac{R(S)}{C}\right]}{R(C)}.$$

Steps (*d*) and (*e*) are taken to give a slope to the mean to any given cycle of Graph IV–4, if the mean were located at the cycle in question. Graph IV–5 is a plot of D.I. versus cycles and is a rate of change of mean net surface damage. Graph IV–6 shows how the slope to the mean of Graph IV–4 is calculated.

Consider Graph IV–6 ($y$ vs. $x$) to be typical of a Calculation 3 $\left(\frac{R(S)}{C} \text{ vs. } C\right)$ graph.

$$y = f(x);$$

$$\text{Area } A = \int_0^x y\,dx = \int_0^x f(x)\,dx;$$

$$\text{Mean ordinate } \bar{y} = \int_0^{x_2} \frac{f(x)\,dx}{x_2};$$

$$\text{Tan } \phi = \frac{\bar{y}}{x_2} = \text{Destructive index or slope to the mean when the mean is moved from } x_1 \text{ to } x_2.$$

Summarizing the steps in calculating the destructive index:

| | | Calculation | Graph |
|---|---|---|---|
| Net surface damage | $= S$ | 1 | IV–3 |
| Running sum of net surface damage | $= R(S)$ | 2 | — |
| Mean net surface damage | $= \frac{R(S)}{C}$ | 3 | IV–4 |
| Running sum of mean net surface damage | $= R\left[\frac{R(S)}{C}\right]$ | 4 | — |
| Slope to the mean (Destructive index) | $= \frac{R\left[\frac{R(S)}{C}\right]}{R(C)}$ | 5 | IV–5 |

As has already been explained, steps ($b$) and ($c$) (Calculations 2 and 3, respectively) account for two different phases of past history—namely, the path by which a curve arrives at a given point (step ($b$)) and the effect of displacement of the origin (step ($c$)). Step ($c$) does not yield values satisfactory for use as a destructive index because the curve IV–4 is a plot of the mean of Graph IV–3. Graph IV–3, however, has not yet taken into account either of the two phases of past history—namely, the path by which the curve arrives at a point or the effect of displacement of the origin. Values from step ($e$) (Calculation 5) yield a rate of change of mean net surface damage and therefore do take past history into account.

It can be shown that Calculation 4 divided by C gives an ordinate as compared with Calculation 5, which is a slope.

Considering Graph IV–4 (Calculation 3) it is possible to take a mean slope instead of the slope to the mean by forming

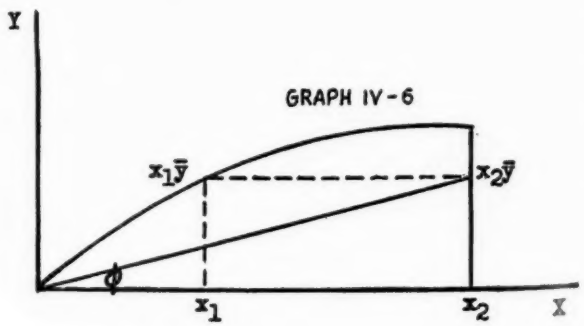
$$\frac{\left[\frac{R(S)}{C}\right]}{C}.$$

This would yield the same mean slope for two curves starting and ending at the same point regardless of path. It is desired, however, to differentiate paths; hence the procedure adopted.

## IV. Combat Course Experiment

A detailed outline of the Combat Course Experiment was designed by representatives of the Quartermaster Board, the Office of The Quartermaster General, the Massachusetts Institute of Technology, and the Fabric Research Laboratories, Inc. In addition to the prime objective of the program—namely, to correlate laboratory with combat course results—the experiment was designed ($a$) to develop a simpler way of evaluating fabric failures; ($b$) to determine the progressive effect of abrasion upon the life of fabrics; ($c$) to compare the wearing properties of the three particular fabrics (herringbone twill, sateen, twill) chosen for the test.

Specially designed two-piece fatigue uniforms were furnished by the Office of The Quartermaster General. In order to obtain the maximum fabric surface upon each uniform with a minimum of buttons, pockets, loops, etc., which might interfere with their evaluation as fabrics, the uniforms were made as simply as possible. All pockets were eliminated; jackets were of the slip-on type with a one-piece front and no buttons; protective flaps were eliminated. Sew-on buttons, instead of tack buttons, were used on the flies of the trousers. All garments were constructed with the warp yarns running longitudinally with the man. The twill and H.B.T. faces and the sateen back were the surfaces tested.



One uniform each of the three different fabrics was assigned to each of fifteen test soldiers. Particular attention was directed toward obtaining an adequate fit on each man. The fifteen test men were divided into three groups of five each and traversed the combat course twice daily according to the following schedule:

| | | 1st five men | 2nd five men | 3rd five men |
|---|---|---|---|---|
| 1st day | First traversal | Herringbone twill (*H*) | *T* | *S* |
| | Second traversal | Twill (*T*) | *S* | *H* |
| 2nd day | Third traversal | Sateen (*S*) | *H* | *T* |

This sequence was continued until fifteen traversals for each garment were made. After each traversal the garments were laundered in a mobile laundry unit with a standard washing formula, after which they were inspected and all damages recorded as to class and size. It must be made clear that *all* damages and not merely *added* or new damages were recorded at each cycle.

It was hoped that each garment could be inspected before and after laundering to determine how much the laundering contributed to fabric destruction. This was found to be impossible, for the unlaundered garments were so caked with dirt and perspiration that many damage areas were hidden. Therefore, they were inspected only after laundering.

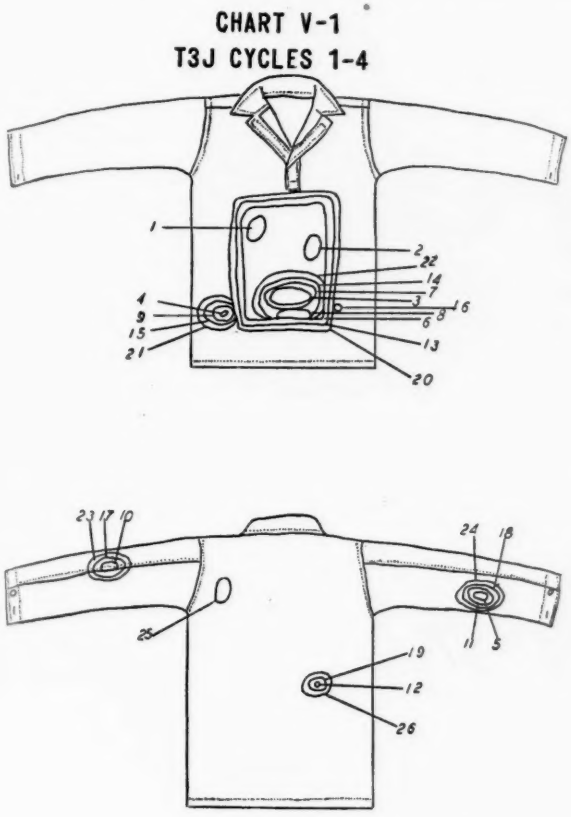
For convenience in recording damages, so that progressive growth in size and change of class (e.g., medium wear to severe) could be observed, the following recording system was used. Twill Jacket No. 3 (T3J) will be used as a representative example.

At each cycle all damages were recorded in tabular form and assigned a chronological number. Corresponding areas of damage with the corresponding numbers were marked on an outline of the jacket (Chart V–1). In this way, if a 2-by-3-inch medium wear on the fourth cycle grew to a 2-by-4-inch severe wear on the fifth cycle, it could immediately be traced and tabulated. Such data for the first four cycles of T3J follow:

| Cycle 1 (recorded in black pencil) | | Cycle 2 (recorded in blue pencil) | |
|---|---|---|---|
| 1 Mild | 2¼″ x 4″ | 6 Mild | 15″ x 7″ |
| 2 Mild | 5″ x 2″ | 7 Medium | 4½″ x 1½″ |
| 3 Medium | 3″ x 1″ | 8 Medium | 4″ x 1¼″ |
| 4 Mild | 1″ x ⅛″ | 9 Mild | 1¾″ x ¼″ |
| 5 Mild | ½″ x ¼″ | 10 Mild | ¼″ x ⅛″ |
| | | 11 Mild | 2½″ x 2½″ |
| | | 12 Medium | ¼″ x ¼″ |

| Cycle 3 (recorded in green pencil) | | Cycle 4 (recorded in red pencil) | |
|---|---|---|---|
| 13 Mild | 8″ x 13″ | 20 Mild | 8″ x 13″ |
| 14 Medium | 5½″ x 1½″ | 21 Mild | 2½″ x 2½″ |
| 15 Mild | 1½″ x ⅜″ | 22 Medium | 7″ x 1½″ |
| 16 Mild | ¾″ x ¼″ | 23 Mild | 5½″ x 5″ |
| 17 Mild | 4½″ x 2″ | 24 Mild | 6″ x 2½″ |
| 18 Mild | 6″ x 2″ | 25 Mild | 3½″ x 1″ |
| 19 Mild | ¼″ x ¼″ | 26 Mild | ¼″ x ¼″ |

In some cases a more severe damage occurred in a less severe damage area. For example, on Cycle 2 a 4½-by-1½-inch medium wear occurred in a 15-by-7-inch mild wear area. Such occurrences were carefully noted on the tabulation sheets.




## V. Representative Combat Course Destructive Index Calculation

All individual damages having been classified, to obtain the total area of mild, medium, severe, etc., damages at any cycles, it was necessary only to sum individual areas in each class.

There is one modification to the above procedure. Consider the case (Cycle 2) in which the 4½-by-1½-inch medium wear occurred in the 15-by-7-inch mild wear area. If the 15-by-7-inch mild were included in the mild summation, and the 4½-by-1½-inch medium lying therein were included in the medium

TABLE VI–1

| Cycle | Mild | Medium | Severe | Holes in wear | Hole |
|---|---|---|---|---|---|
| 1 | $2\frac{1}{4}$ x 4 | | | | |
| | 5 x 2 | | | | |
| | | 3 x 1 | | | |
| | 1 x $1\frac{1}{8}$ | | | | |
| | $\frac{1}{2}$ x $\frac{1}{4}$ | | | | |
| 2 | 15 x 7 | | | | |
| | $-(4\frac{1}{2}$ x $1\frac{1}{2})$ | $4\frac{1}{2}$ x $1\frac{1}{2}$ | | | |
| | $-(4$ x $1\frac{1}{4})$ | 4 x $1\frac{1}{4}$ | | | |
| | $1\frac{3}{4}$ x $\frac{1}{4}$ | | | | |
| | $\frac{1}{4}$ x $\frac{1}{8}$ | | | | |
| | $2\frac{1}{2}$ x $2\frac{1}{2}$ | | | | |
| | $\frac{1}{4}$ x $\frac{1}{4}$ | | | | |
| 3 | 8 x 13 | | | | |
| | $-(5\frac{1}{2}$ x $1\frac{1}{2})$ | $5\frac{1}{2}$ x $1\frac{1}{2}$ | | | |
| | $1\frac{1}{2}$ x $\frac{3}{8}$ | | | | |
| | $\frac{3}{4}$ x $\frac{1}{4}$ | | | | |
| | $4\frac{1}{2}$ x 2 | | | | |
| | 6 x 2 | | | | |
| | $\frac{1}{4}$ x $\frac{1}{4}$ | | | | |
| 4 | 8 x 13 | | | | |
| | $2\frac{1}{2}$ x $2\frac{1}{2}$ | | | | |
| | $-(7$ x $1\frac{1}{2})$ | 7 x $1\frac{1}{2}$ | | | |
| | $5\frac{1}{2}$ x 5 | | | | |
| | 6 x $2\frac{1}{2}$ | | | | |
| | $3\frac{1}{2}$ x 1 | | | | |
| | $\frac{1}{4}$ x $\frac{1}{4}$ | | | | |

TABLE VI–2. NET SURFACE DAMAGE (S) (CALCULATION 1)

| | Jacket T3J Area in Square Inches | | | | |
|---|---|---|---|---|---|
| Cycles | Mild | Medium | Severe | Hole in wear | Hole |
| 1 | 20.25 | 3.00 | | | |
| 2 | 100.03 | 11.75 | | | |
| 3 | 117.56 | 8.25 | | | |
| 4 | 145.81 | 10.50 | | | |
| 5 | 160.69 | 37.30 | 0.20 | | |
| 6 | 172.23 | 36.71 | 0.96 | 0.04 | |
| 7 | 255.16 | 79.05 | 1.03 | 0.05 | |
| 8 | 235.83 | 104.13 | 1.23 | 0.14 | |
| 9 | 372.14 | 111.55 | 2.35 | 0.10 | |
| 10 | 362.39 | 108.30 | 6.99 | 0.21 | |
| 11 | 362.39 | 108.30 | 6.99 | 0.21 | |
| 12 | 327.64 | 100.42 | 4.79 | 0.29 | |
| 13 | 343.52 | 120.38 | 4.58 | 0.32 | |
| 14 | 397.02 | 108.67 | 13.61 | 0.35 | |
| 15 | 368.58 | 107.26 | 16.27 | 0.53 | |

TABLE VI–3. D.I. CALCULATION SEQUENCE (MEDIUM WEAR)

| | Jacket T3J Calculation | | | | |
|---|---|---|---|---|---|
| Cycles | 1 | 2 | 3 | 4 | 5 |
| 1 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| 2 | 11.75 | 14.75 | 7.38 | 10.38 | 3.46 |
| 3 | 8.25 | 23.00 | 7.67 | 18.05 | 3.01 |
| 4 | 10.50 | 33.50 | 8.38 | 26.43 | 2.64 |
| 5 | 37.30 | 70.80 | 14.16 | 40.59 | 2.71 |
| 6 | 36.71 | 107.51 | 16.25 | 56.84 | 2.71 |
| 7 | 79.05 | 186.56 | 26.65 | 83.49 | 2.98 |
| 8 | 104.13 | 290.69 | 36.34 | 119.83 | 3.33 |
| 9 | 111.55 | 402.24 | 44.69 | 164.52 | 3.66 |
| 10 | 108.30 | 510.54 | 51.05 | 215.57 | 3.92 |
| 11 | 108.30 | 618.84 | 56.26 | 271.83 | 4.12 |
| 12 | 100.42 | 719.26 | 59.94 | 331.77 | 4.25 |
| 13 | 120.38 | 839.64 | 64.59 | 396.36 | 4.36 |
| 14 | 108.67 | 948.31 | 67.74 | 464.10 | 4.42 |
| 15 | 107.26 | 1055.57 | 70.37 | 534.47 | 4.45 |

TABLE VII–1. JACKETS—AVERAGE D.I.—MILD WEAR

TABLE VII–2. TROUSERS—AVERAGE D.I.—MILD WEAR

| Cycle | T.F. | S.B. | H.F. | T.F. | S.B. | H.F. |
|---|---|---|---|---|---|---|
| 1 | 24.20 | 8.46 | 29.57 | 15.83 | 0.07 | 8.76 |
| 2 | 24.01 | 7.70 | 26.04 | 21.47 | 0.85 | 13.22 |
| 3 | 23.14 | 7.07 | 23.43 | 26.08 | 1.85 | 15.64 |
| 4 | 22.48 | 7.03 | 21.72 | 32.19 | 4.09 | 21.16 |
| 5 | 21.56 | 7.83 | 20.46 | 36.62 | 7.56 | 25.44 |
| S.D.* Cycle 5 | 4.86 | 3.82 | 6.21 | 8.81 | 4.12 | 7.73 |
| C.V.† Cycle 5 | 0.23 | 0.49 | 0.30 | 0.24 | 0.55 | 0.30 |
| 6 | 20.70 | 8.61 | 19.39 | 39.56 | 11.05 | 28.87 |
| 7 | 19.85 | 9.28 | 18.37 | 41.94 | 14.37 | 31.58 |
| 8 | 19.13 | 9.75 | 17.49 | 43.68 | 17.55 | 33.69 |
| 9 | 18.59 | 10.22 | 16.84 | 44.81 | 20.27 | 35.33 |
| 10 | 18.17 | 10.65 | 16.37 | 45.46 | 22.47 | 36.53 |
| S.D.* Cycle 10 | 2.31 | 2.66 | 2.48 | 7.08 | 5.57 | 5.18 |
| C.V.† Cycle 10 | 0.13 | 0.25 | 0.15 | 0.16 | 0.25 | 0.14 |
| 11 | 17.80 | 11.01 | 15.98 | 45.67 | 24.19 | 37.32 |
| 12 | 17.43 | 11.27 | 15.63 | 45.56 | 25.52 | 37.79 |
| 13 | 17.07 | 11.44 | 15.28 | 45.23 | 26.52 | 37.99 |
| 14 | 16.73 | 11.56 | 14.96 | 44.73 | 27.23 | 37.99 |
| 15 | 16.38 | 11.63 | 14.64 | 44.17 | 27.73 | 37.82 |
| S.D.* Cycle 15 | 1.96 | 2.06 | 1.62 | 5.97 | 4.43 | 4.45 |
| C.V.† Cycle 15 | 0.12 | 0.18 | 0.11 | 0.14 | 0.16 | 0.12 |

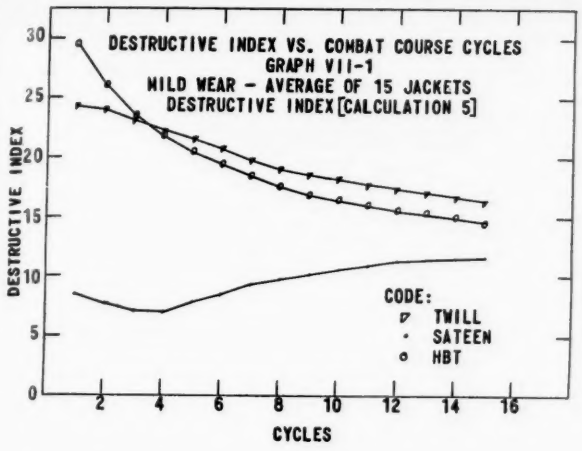
* S.D.—Standard deviation.
† C.V.—Coefficient of variation.

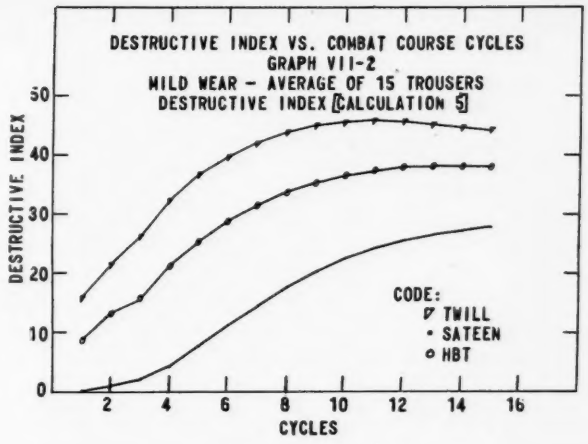
summation, the medium would be counted twice—once as part of the 15-by-7-inch mild and once as a $4\frac{1}{2}$-by-$1\frac{1}{2}$-inch medium. Therefore, wherever a more severe wear area lies in a less severe area, in summing the less severe areas, the more severe area must be subtracted out to give the *net* less severe area.

Thus $4\frac{1}{2}$ in. × $1\frac{1}{2}$ in. = 6.8 in.$^2$ medium must be subtracted from the 15 in. × 7 in. = 105 in.$^2$ mild to give a mild net area of 105 − 6.8 = 98.2 in.$^2$

By this method, the total damaged area of all classes can never exceed the total area of the garment.

A mild area on a subsequent cycle may become, in whole or in part, a medium area. This increases the medium and decreases the net mild area over




corresponding values of the preceding cycle. The same situation may also occur for medium, severe, and hole damages. It cannot occur in the case of hole in wear because a hole in wear cannot change to a more severe class. Thus mild-, medium-, severe-, and hole-versus-cycles graphs can either increase or decrease as the damage becomes worse and progresses from one class to another. Hole-in-wear-versus-cycles graphs can only increase.

The relationship between different damage classes with respect to their detracting from the serviceability of the garment will be discussed in Section VII–B.

Continuing the analysis of Jacket T3J for the first four cycles and separating the damages into classes gives the results listed in Table VI–1.

Areas in parenthesis are mediums lying in mild areas and hence must be subtracted from the mild areas before the mild areas are summed. (For the first four cycles on this garment no severes, holes in wear, or holes occurred.)

Summing the areas, mild and medium, for the first four cycles gives:

| Cycle | Mild | Medium |
|---|---|---|
| 1 | 20.3 | 3.0 |
| 2 | 100.0 | 11.8 |
| 3 | 117.6 | 8.3 |
| 4 | 145.8 | 10.5 |

Since there are no severe areas it is theoretically impossible for an 11.8 medium on Cycle 2 to diminish to 8.3 on Cycle 3. The fact that it does reflects the garment inspectors' inability to measure the damaged areas with absolute precision.

Table VI–2 tabulates net areas for fifteen cycles for each damage class for T3J.

Graph IV–3 is a representative plot of net surface damage ($S$) versus cycles for medium wear on twill Jacket No. 3 (T3J).

From a table and a graph of net surface damage ($S$) versus cycles, the destructive index may be calculated. Repeating the mathematical steps as outlined in Section III–B–3 gives:

Calculation

1 $S$ (net surface damage)

2 $R(S)$

3 $\frac{R(S)}{C}$ (mean net surface damage)

4 $R\left[\frac{R(S)}{C}\right]$

5 $\frac{R\left[\frac{R(S)}{C}\right]}{R(C)}$ (destructive index)

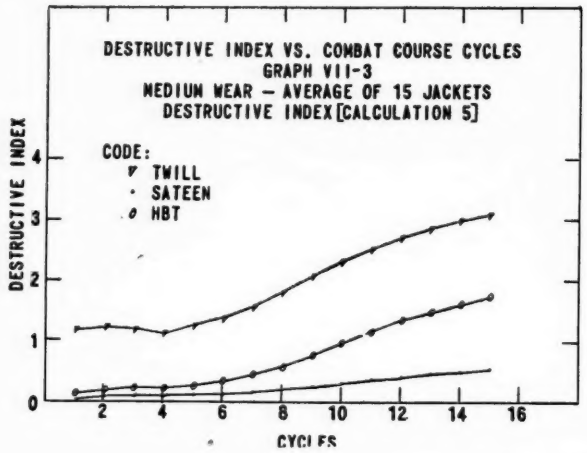
Table VI–3 shows these calculations step by step for medium wear on T3J.

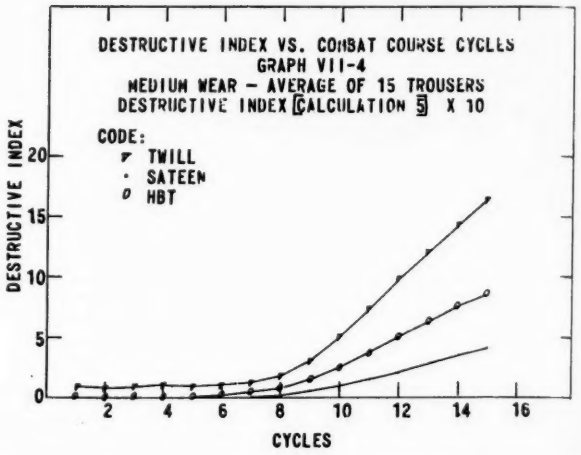
Graph IV–4 is a representative plot of mean net surface damage versus cycles (Calculation 3 versus cycles) for medium T3J.

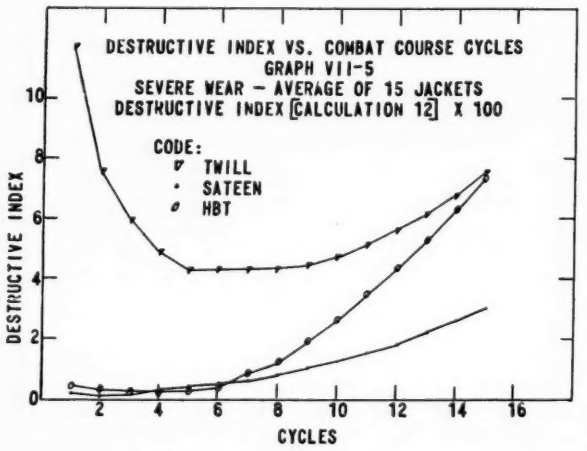
Graph IV–5 is a plot of destructive index versus cycles (Calculation 5 versus cycles) for medium T3J.

## VI. Combat Course Results

Tables VII–1 and VII–2 list average D.I.'s for the twill, sateen, and H.B.T. garments for each cycle for mild wear and are representative of like tables for the other damage classes. Graphs VII–1 and VII–2 are plots of D.I. versus cycles for these data. Similarly, Graphs VII–3 to VII–10 plot D.I. values for the other damage classes (Graph VII–9 is omitted because in no case were there sufficient holes to warrant consideration).




## VII. Discussion of Combat Course Results

### *A. Destructive Indices Within a Damage Class*

Destructive indices at the end of the fifteenth cycle may be used to evaluate wear-resistance of the garment for its entire previous history up to and including this cycle.

Statistical analysis of the data shows high variability.

Table VIII–2 records tests for the existence of significant differences between pairs of fabrics, using the normal t. test. Both 95 percent and 90 percent significance levels are included.

The difference between D.I.'s is significant if it exceeds the "critical difference."

#### Discussion of Tables VIII–1 and VIII–2

*Mild.* At the higher significance level all differences for jackets and trousers are significant.

Rank: Jacket—Sateen best, H.B.T. next, twill worst.

Trousers—Sateen best, H.B.T. next, twill worst.

*Medium.* At the higher significance level all differences for jackets and trousers are significant.

Rank: Jackets—Sateen best, H.B.T. next, twill worst.

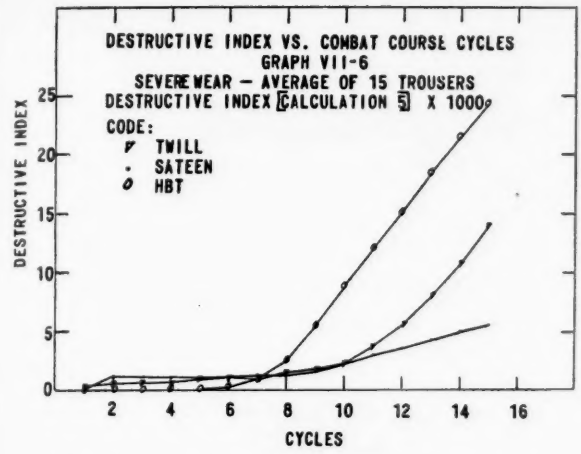
Trousers—Sateen best, H.B.T. next, twill worst.

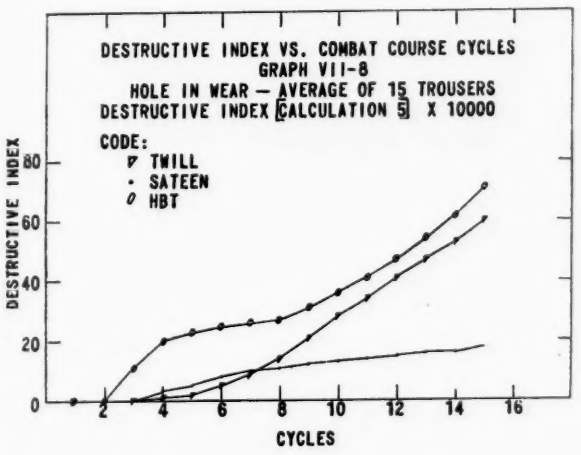
*Severe.* Jacket—At the 95 percent level no significant differences exist. Differences between *TF* vs. *SB*, and *HF* vs. *SB* are almost significant, however. At the 90 percent level they are significantly

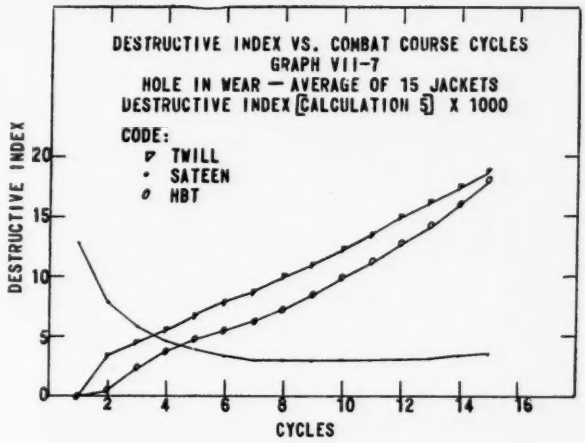
TABLE VIII–1. Average Destructive Indices at Fifteenth Cycle

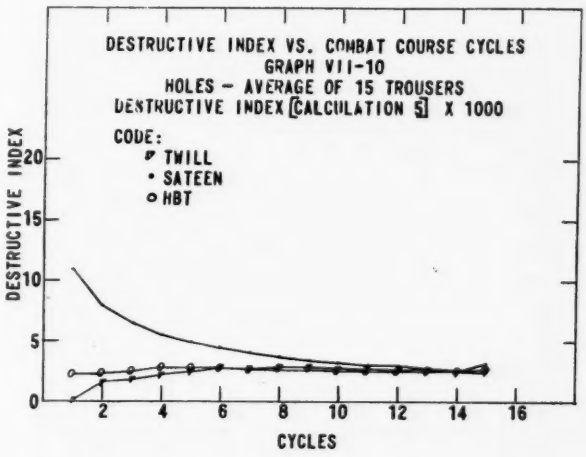
| | Jackets | | | Trousers | | |
|---|---|---|---|---|---|---|
| | T.F. | S.B. | H.F. | T.F. | S.B. | H.F. |
| Mild | | | | | | |
| Mean | 16.38 | 11.63 | 14.64 | 44.17 | 27.73 | 37.83 |
| S.D.* | 1.96 | 2.06 | 1.62 | 5.97 | 4.43 | 4.45 |
| C.V.† | 0.12 | 0.18 | 0.11 | 0.14 | 0.16 | 0.12 |
| Medium | | | | | | |
| Mean | 3.10 | 0.54 | 1.75 | 1.62 | 0.41 | 0.86 |
| S.D.* | 1.02 | 0.36 | 0.63 | 0.52 | 0.25 | 0.39 |
| C.V.† | 0.33 | 0.67 | 0.36 | 0.32 | 0.61 | 0.45 |
| Severe | | | | | | |
| Mean | 0.0758 | 0.0301 | 0.0735 | 0.0138 | 0.0054 | 0.0242 |
| S.D.* | 0.0872 | 0.0525 | 0.0915 | 0.0186 | 0.0098 | 0.0431 |
| C.V.† | 1.15 | 1.74 | 1.25 | 1.35 | 1.82 | 1.78 |
| Hole in wear | | | | | | |
| Mean | 0.0187 | 0.0036 | 0.0180 | 0.0060 | 0.0018 | 0.0071 |
| S.D.* | 0.0299 | 0.0044 | 0.0338 | 0.0188 | 0.0044 | 0.0092 |
| C.V.† | 1.61 | 1.22 | 1.87 | 3.13 | 2.44 | 1.30 |
| Hole | | | | | | |
| Mean | — | — | — | 0.0025 | 0.0032 | 0.0027 |
| S.D.* | — | — | — | 0.0043 | 0.0049 | 0.0046 |
| C.V.† | — | — | — | 1.72 | 1.53 | 1.70 |

* Standard deviation.
† Coefficient of variation.




different. There is no significant difference between twill and H.B.T.

Trousers—At both significance levels there is a significant difference between *HF* vs. *SB*. There is no significant difference between *TF* vs. *SB* and *TF* vs. *HF*.

TABLE VIII-2. CRITICAL DIFFERENCES AND DIFFERENCES BETWEEN AVERAGE D.I.'s

| | Critical differences | | Difference between D.I.'s | | |
|---|---|---|---|---|---|
| | 95% Significance level | 90% Significance level | *TF vs. SB* | *HF vs. SB* | *TF vs. HF* |
| | | Jackets | | | |
| Mild | 1.19 | 1.00 | 4.75 | 3.01 | 1.74 |
| Medium | 0.39 | 0.33 | 2.56 | 1.21 | 1.35 |
| Severe | 0.0476 | 0.0400 | 0.0457 | 0.0434 | 0.0023 |
| Hole in wear | 0.0194 | 0.0163 | 0.0151 | 0.0145 | 0.0006 |
| | | Trousers | | | |
| Mild | 2.77 | 2.33 | 16.44 | 10.09 | 6.35 |
| Medium | 0.2404 | 0.203 | 1.21 | 0.45 | 0.76 |
| Severe | 0.0176 | 0.0148 | 0.0084 | 0.0188 | 0.0104 |
| Hole in wear | 0.0078 | 0.0065 | 0.0042 | 0.0053 | 0.0011 |
| Hole | 0.0028 | 0.0023 | 0.0007 | 0.0005 | 0.0002 |

Rank: Jackets—Sateen best; no difference between twill and H.B.T.
Trousers—Sateen probably best; twill probably next; H.B.T. probably worst.

*Hole in Wear.* While for both jackets and trousers no significant differences exist, differences between sateen and the other two fabrics approach significance to a much greater extent than do those between twill and H.B.T.

Rank: Jackets—Sateen best; no difference between twill and H.B.T.
Trousers—Sateen best; no difference between twill and H.B.T.

*Hole.* All differences are insignificant. Holes are fortuitous.

Summarizing, it is evident that the sateen back is the best and that there is no significant difference between twill and H.B.T. The H.B.T. might be slightly better.

TABLE VIII–3. WARP TENSILE STRENGTH OF COMBAT COURSE FABRICS

*Before Subjection to Combat Course*

Original strength (in pounds)

| Twill | Sateen | H.B.T. |
|---|---|---|
| 158 | 143 | 125 |

*After Subjection to 20 Combat Course Cycles*

Strength (in pounds)

| | *Twill* | | | | *Sateen* | | | | *H.B.T.* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jacket No. 3 | No wear | Mild | Medium | Severe | No wear | Mild | Medium | Severe | No wear | Mild | Medium | Severe |
| (1) Breaking strength ($\bar{x}$) | 134.0 | 102.9 | 61.6 | 41.6 | 114.0 | 106.5 | 66.2 | 44.8 | 101.6 | 84.4 | 54.9 | 13.0 |
| (2) $S$ | 15.6 | 29.8 | 19.0 | 12.9 | 23.4 | 18.1 | 14.7 | 11.0 | 9.8 | 14.9 | 23.5 | 6.2 |
| (3) $S/\bar{x}$ | 11.6 | 28.9 | 30.8 | 31.0 | 20.5 | 17.0 | 22.2 | 24.6 | 9.6 | 17.7 | 42.8 | 47.7 |
| (4) $n$ | 5 | 10 | 8 | 5 | 8 | 10 | 8 | 2 | 6 | 16 | 13 | 4 |
| (5) % Reduction | 15.2 | 34.8 | 61.0 | 73.7 | 20.3 | 25.5 | 53.7 | 68.7 | 18.4 | 32.5 | 56.1 | 89.6 |
| Jacket No. 8 | | | | | | | | | | | | |
| (1) Breaking strength ($\bar{x}$) | 143.5 | 133.1 | 93.1 | 54.8 | 132.0 | 126.3 | 108.9 | 66.1 | 111.9 | 101.8 | 71.3 | 43.8 |
| (2) $S$ | 9.2 | 24.2 | 13.7 | 25.6 | 4.7 | 12.0 | 37.4 | 25.8 | 7.3 | 11.0 | 14.9 | 9.5 |
| (3) $S/\bar{x}$ | 6.4 | 18.2 | 14.7 | 46.7 | 3.6 | 9.5 | 34.3 | 39.0 | 6.5 | 10.8 | 20.9 | 21.7 |
| (4) $n$ | 8 | 10 | 7 | 9 | 4 | 10 | 9 | 6 | 8 | 8 | 8 | 6 |
| (5) % Reduction | 9.2 | 15.8 | 41.1 | 65.3 | 7.7 | 11.7 | 23.8 | 53.8 | 10.5 | 18.6 | 43.0 | 65.0 |
| Trouser No. 3 | | | | | | | | | | | | |
| (1) Breaking strength ($\bar{x}$) | 123.9 | 115.1 | 84.1 | 54.0 | 118.1 | 109.6 | 86.8 | 60.0 | 95.9 | 90.5 | 66.9 | 29.8 |
| (2) $S$ | 13.3 | 21.9 | 23.9 | 18.0 | 17.8 | 12.5 | 21.2 | 7.7 | 10.5 | 13.5 | 18.5 | 15.2 |
| (3) $S/\bar{x}$ | 10.7 | 19.0 | 28.4 | 33.3 | 15.1 | 11.4 | 24.4 | 12.8 | 10.9 | 14.9 | 27.7 | 51.0 |
| (4) $n$ | 13 | 11 | 16 | 8 | 20 | 23 | 5 | 6 | 10 | 18 | 16 | 6 |
| (5) % Reduction | 21.6 | 27.2 | 46.8 | 65.8 | 17.4 | 23.4 | 39.3 | 58.0 | 23.3 | 27.6 | 46.5 | 76.2 |
| Trouser No. 8 | | | | | | | | | | | | |
| (1) Breaking strength ($\bar{x}$) | 122.7 | 102.6 | 91.5 | 46.0 | 124.3 | 107.8 | 103.6 | — | 96.8 | 87.3 | 67.2 | — |
| (2) $S$ | 14.8 | 24.0 | 15.4 | — | 7.6 | 17.4 | 25.3 | — | 13.0 | 11.4 | 18.0 | — |
| (3) $S/\bar{x}$ | 12.1 | 23.4 | 16.8 | — | 6.1 | 16.1 | 24.4 | — | 13.4 | 13.1 | 26.8 | — |
| (4) $n$ | 10 | 10 | 10 | 1 | 10 | 10 | 10 | — | 10 | 10 | 10 | — |
| (5) % Reduction | 22.3 | 35.1 | 42.1 | 71.0 | 13.1 | 24.6 | 27.5 | — | 22.6 | 30.2 | 46.2 | — |
| Grand Average 6% Reduction | 18.2% | 27.6% | 47.3% | 67.5% | 16.0% | 21.8% | 35.2% | 57.7% | 19.2% | 28.2% | 47.5% | 75.3% |

As the damage classes become more severe, differences between fabrics become less. In this investigation, three cotton fabrics of substantially comparable weight, strength, and thickness were being studied. The variables are such geometric factors as weave, twist, sett, float length, percent warp and filling surface. As the magnitudes of the forces that cause damage increase, these geometric factors become less important in rendering a fabric abrasion-resistant.

To carry the point to extremes, if cotton fabrics of equal thickness and weight are cut with a knife, it makes no difference what the geometric differences are. The force is so great that differences in resistance become negligible.

Under such conditions, the resistance to damage is inherent in the fiber. Thus, as damage class gets worse, significant differences due to fabric geometry become less.

From this Combat Course experiment it is apparent that fifteen men are a minimum number of subjects required to conduct a test. Twenty, twenty-five, or even thirty men would give much more reliable results. Of course the number of men is a function of the wear-resistance of the fabrics being tested. If great differences exist between fabrics, five men might be sufficient to prove such differences. The use of fewer than fifteen men is not recommended, however.

### *B. Destructive Indices Among Damage Classes*

The previous section analyzes D.I.'s for each damage class but does not combine them to calculate an

over-all destructive index. Calculation of such a Combined D.I. requires a quantitative relationship between mild, medium, severe, hole-in-wear, and hole damage classes. The relationship between damage classes is complex and depends to a large degree upon philosophy. How much worse is a hole in wear of a given area than a medium wear of equal area? A hole offers no protection to the wearer. A medium wear may afford the same protection as an unworn area; yet the residual life of the medium area is less. In this investigation, it is felt that interest lies in the extent of damage and the rate at which damage occurs. Hence a medium area is considered to be worse than an unworn area because its residual strength and life are less.

Laboratory-abraded fabrics have been ranked using tensile strength loss as a criterion of damage from abrasion.* In the same way mild, medium, severe, hole-in-wear, and hole damages also can be ranked by use of strength loss methods.

In evaluating garments worn on the Combat Course, the observer made a decision as to the class and size of each damage. While it was decided that scuffing denoted mild wear, broken fibers denoted medium wear, and broken yarns severe wear, a great amount of personal opinion entered into the scoring for these three classes. In the case of severes, holes-in-wear, and holes, the damages were more clearly defined and measurable; therefore less personal error was involved. As a means of relating damage classes, and also to check the consistency of the observer's ability to grade mild, medium, and severe damages, tensile strength measurements were made on the Combat Course garments after they had been subjected to twenty Combat Course cycles.

The same observer who classified and scored all garments during the Combat Course experiment selected unabraded, mild, medium, and severe areas from these Combat Course garments. One-inch-wide raveled strip warp tensile test samples were prepared and broken on the testing machine. Warp tests were made because tensions on the Combat Course (as will be shown in Section XII) are predominantly warpwise. Table VIII–3 shows tensile strengths and percent tensile strength losses for mild, medium, and severe classes for each fabric. Holes in wear and holes are considered to have suffered 100 percent strength loss; no strengths were measured.

### EXPLANATION OF TABLE VIII–3

The original strengths of fabrics before subjection to the Combat Course are given at the top of each section for twill, sateen, and H.B.T.

The column marked "No wear" shows the strength of areas in which no observable wear occurred after twenty Combat Course cycles.

Row 1 shows average breaking strength for a 1-inch raveled strip sample and a 1-inch gage length ($\bar{x}$).

Row 2 shows the standard deviation of the breaking strength

$$\left(S = \sqrt{\frac{(x - \bar{x})^2}{n - 1}}\right).$$

Row 3 shows the coefficient of variation (C.V. $= S/\bar{x}$).

Row 4 shows the number of samples broken ($n$).

Row 5 shows the average percent reduction in strength based upon the original strength of the fabrics before subjection to the Combat Course.

Row 6 (bottom of table) shows the grand average percent reduction in strength for Jackets 3 and 8 and Trousers 3 and 8. The average is weighted in terms of the number of specimens tested in each case.

Statistical analysis shows that in each case there is no significant difference in percent strength loss between the twill and H.B.T. There is a significant difference between the sateen and the other two, the sateen always showing a smaller percent of strength loss and therefore greater residual strength. A medium wear, as the observer saw it, is not so deleterious for the sateen as for the other fabrics. Calling it "medium" tends to penalize the sateen, for all medium areas are summed and a destructive index is calculated therefrom.

It is felt that the correlation between percent strength loss and damage classes is good, considering the fact that so much personal opinion entered into the scoring of the garments.

In those areas wherein no wear was visible to the eye and where the fabric looked to be "as good as new," a strength loss of from 16 to 19 percent occurred ("No wear" column). It is somewhat surprising to learn that fabrics suffer such a strength loss with no apparent damage having occurred.

In weighting and then combining destructive indices of the different damage classes, use of percent

* Section VIII in Part II of this study will explain why tensile strength was chosen rather than some other physical measurement, such as loss in thickness, weight, etc.

TABLE VIII–4. COMBINED DESTRUCTIVE INDICES

| | Jackets | | | Trousers | | |
|---|---|---|---|---|---|---|
| Cycle | Twill | Sateen | H.B.T. | Twill | Sateen | H.B.T. |
| 1 | 7.32 | 1.87 | 8.43 | 4.41 | 0.03 | 2.47 |
| 2 | 7.27 | 1.72 | 7.45 | 5.96 | 0.20 | 3.73 |
| 3 | 7.00 | 1.58 | 6.73 | 7.24 | 0.41 | 4.60 |
| 4 | 6.78 | 1.57 | 6.25 | 8.93 | 0.90 | 5.97 |
| 5 | 6.59 | 1.75 | 5.91 | 10.15 | 1.66 | 7.18 |
| 6 | 6.41 | 1.93 | 5.65 | 10.97 | 2.42 | 8.16 |
| 7 | 6.27 | 2.08 | 5.41 | 11.64 | 3.15 | 8.93 |
| 8 | 6.18 | 2.20 | 5.23 | 12.14 | 3.84 | 9.54 |
| 9 | 6.16 | 2.32 | 5.15 | 12.52 | 4.44 | 10.04 |
| 10 | 6.16 | 2.43 | 5.11 | 12.79 | 4.94 | 10.43 |
| 11 | 6.17 | 2.53 | 5.10 | 12.96 | 5.33 | 10.72 |
| 12 | 6.15 | 2.60 | 5.09 | 13.05 | 5.64 | 10.91 |
| 13 | 6.13 | 2.66 | 5.08 | 13.07 | 5.88 | 11.04 |
| 14 | 6.10 | 2.70 | 5.06 | 13.04 | 6.06 | 11.09 |
| 15 | 6.06 | 2.74 | 5.04 | 12.98 | 6.20 | 11.10 |

strength losses is one weighting method. For example, the twill hole-in-wear D.I.'s may be multiplied by 100 percent because a hole in wear has suffered 100 percent loss; severe D.I.'s may be multiplied by 67.5 percent; mediums by 47.3 percent; and milds by 27.6 percent; the resulting products would then be summed to give a combined D.I. Such a weighting results in a hole in wear of unit area being approximately four times as bad as a mild of unit area (100/27.6 = approximately 4). It can be argued that this ratio is far too small. If such is the case, at the present writing no way of combining damage classes is known and it is recommended that the classes be kept separate. There are distinct advantages in doing this; each may then be considered in terms of serviceability, thus:

Mild and medium destructive index curves rank the appearance of the fabrics after normal wear and may be used in evaluating dress fabrics where appearance is important. Severe, hole-in-wear, and hole destructive index curves may be used to evaluate the serviceability and utility of the fabrics where appearance is not important. In evaluating Combat Course fabrics, severe, hole-in-wear, and hole destructive indices are of course the governing classes. However, for the three fabrics tested all classes rank the fabrics substantially the same, and there is no reason to discount the mild or medium D.I.'s.

If D.I.'s *are* combined, using percent strength losses as weighting factors, some extremely relevant relationships between the twill, sateen, and H.B.T. result. A combined D.I. was calculated by averaging net surface damage ($S$) for the fifteen garments at each cycle for each damage class ($\bar{S}$), weighting the average ($\bar{S}$) by its percent strength loss, summing weighted ($\bar{S}$) of the various classes, and then calculating a combined D.I. in the regular manner:

$\bar{S}_{mild}, \bar{S}_{medium}, \bar{S}_{severe}$, etc. = Average net surface damage of 15 garments at any cycle.

$\%L_{mild}, \%L_{medium}, \%L_{severe}$, etc. = Percent loss in strength for each damage class.

$\bar{S}_w = (\bar{S}_{mild} \times \%L_{mild}) + (\bar{S}_{medium} \times \%L_{medium}) + \text{etc.}$ = Average weighted total surface damage.

Then:

$$\text{Calculation } 1 = \bar{S}_w$$

$$2 = R(\bar{S}_w)$$

$$3 = \frac{R(\bar{S}_w)}{C}$$

$$4 = R\left[\frac{R(\bar{S}_w)}{C}\right]$$

$$5 = \frac{R\left[\frac{R(\bar{S}_w)}{C}\right]}{R(C)} = \text{Combined D.I.}$$

Table (VIII–4) tabulates combined D.I.'s for each fabric, at each cycle. Graph (VIII–5) plots the same data.

Analyzing combined D.I.'s at the end of the fifteenth cycle, jackets and trousers both show that the sateen is by far the best, H.B.T. is next best, and twill is worst. The difference between twill and H.B.T. is less than that between either the twill and sateen or H.B.T. and sateen.

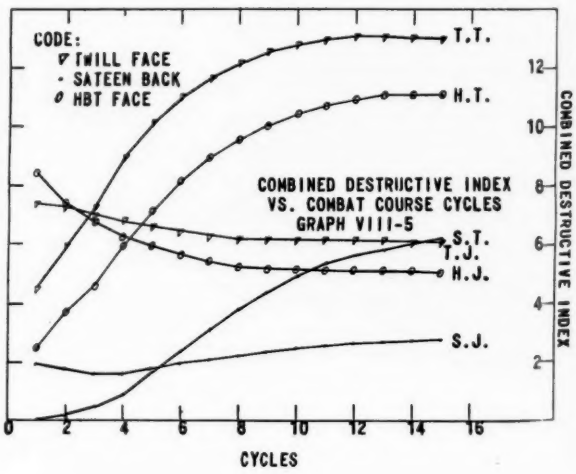


TABLE VIII–6. COMBINED DESTRUCTIVE INDEX RATIOS—END OF FIFTEENTH CYCLE

| Jackets | Trousers |
|---|---|
| $\frac{TF}{SB} = \frac{6.06}{2.74} = 2.21$ | $\frac{TF}{SB} = \frac{12.98}{6.20} = 2.09$ |
| $\frac{HF}{SB} = \frac{5.04}{2.74} = 1.84$ | $\frac{HF}{SB} = \frac{11.10}{6.20} = 1.79$ |
| $\frac{TF}{HF} = \frac{6.06}{5.04} = 1.20$ | $\frac{TF}{HF} = \frac{12.98}{11.10} = 1.17$ |

TABLE VIII–7. COMBINED DESTRUCTIVE INDICES—END OF FIFTEENTH CYCLE

| Ratio of Trouser to Jacket |
|---|
| Twill $= \frac{Tr}{J} = \frac{12.98}{6.06} = 2.14$ |
| Sateen $= \frac{Tr}{J} = \frac{6.20}{2.74} = 2.26$ |
| H.B.T. $= \frac{Tr}{J} = \frac{11.10}{5.04} = 2.20$ |

Because of the complexity of combining damage classes and the ensuing D.I. calculation, no statistical analysis of the combined D.I.'s has been made. The greater portion of the combined D.I.'s is contributed by the wear classes. This is true because the net surface damage ($S$) for wears is much greater than for holes in wear or holes. The uncombined D.I.'s (Section VII–A) for the wear classes show significant differences among the three fabrics. Therefore it is apparent that the difference in combined D.I. between sateen and the other two fabrics is significant. The difference between twill and H.B.T. is probably significant but of course the magnitude of the difference is smaller.

Ratios of twill to sateen, H.B.T. to sateen, and twill to H.B.T. are given in Table VIII–6.

Excellent agreement exists between jackets and trousers. For example, the twill has 2.21 times the combined D.I. of the sateen for the jackets and 2.09 for the trousers. Again it should be pointed out that these results apply only to the twill and herringbone faces and to the sateen back, as they were made into the test garments wherein the warp yarns run vertically.

Comparison of jacket and trouser combined D.I.'s for each fabric is shown in Table VIII–7.

The ratio of trouser to jacket damage is apparently constant and independent of the fabric. Since the combined D.I. is a function of net surface damage ($S$), the fact that the trouser values are 2.2 times the jacket values does not mean that the trousers are wearing out twice as fast as the jackets. The area of available trouser damage is not the same as for jackets; hence no comparison can be made. The destructive index may be used only to compare garments of the same type and of the same general dimension. Future work might profitably be carried out in studying the relationship between the true rate at which jackets and trousers wear out.

Summarizing, the results of the Combat Course test experiment show that

1. The sateen wears out slowest and is therefore best.
2. The H.B.T. wears out 1.8 times faster than the sateen and is next best.
3. The twill wears out 2.1 times faster than the sateen and is worst.
4. The twill probably wears out slightly faster than the H.B.T. The difference between them is small compared with differences between twill and sateen, and H.B.T. and sateen.

## Acknowledgment

Members of the following organizations gave unstintingly of their time and efforts to this project: Office of The Quartermaster General, Camp Lee Quartermaster Board, National Research Council, Textile Division of the Massachusetts Institute of Technology, and the Fabric Research Laboratories, Inc. Grateful acknowledgment is made also to Professor Edward R. Schwarz, Kenneth R. Fox, Cyril M. Krook, and Walter J. Hamburger for their assistance and counsel; also to Miss Barbara J. Glidden for her painstaking efforts in the laboratory testing and assembling of data.

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# Influence of Fiber Structure of Rayon on Swelling and Radial Density

*Report on Textile Research at the Textile Chemical Institute of the Mulhouse-Alsace Technical College*

**Herbert F. Schiefer* and Richard T. Kropf***

## I. Foreword

The information contained in this report was obtained from Prof. Egon Elöd, formerly director of the Textile Chemical Institute at the Mulhouse-Alsace Technical College and also professor at the Karlsruhe Institute of Technology. Professor Elöd was interrogated by the authors in September, 1945, at Badenweiler, Germany, where he had set up a provisional laboratory in the 5- or 6-room cooking house of the former Grand Duchess of Baden. He and a staff of about 15 of his former associates at Mulhouse had been conducting research at Badenweiler since about the middle of 1944. Professor Elöd and a staff of about 60 had carried out important research in the well-equipped laboratories at Mulhouse on the structure, dyeing, and chemistry of protein, cellulose, and nylon. A list of the papers published since 1941 is included as Part III of this report. A copy of an unpublished manuscript by Elöd and Fröhlich was obtained from Kurt Mierisch, Technical Editor of *Melliand Textilberichte* at Heidelberg. This manuscript has been translated and constitutes Part II of this report.

## II. Influence of Fiber Structure of Rayon on Swelling and Radial Density

### *1. Introduction*

Natural and synthetic cellulosic fibers differ considerably in their behavior towards water; for example, in swelling and wet strength. Theoretical considerations led Elöd to conclude that the basic differences between these fibers is partly ascribable to a variation in density and in the character and manner of packing of the cellulosic structural units. The density depends upon the spacings of these units and upon the distances between molecular linkages. By character or manner of packing is meant the density distribution; that is, variation of density in the successive concentric layers of the cross section of a fiber. In comparable experiments the density is therefore a measure of these fiber structural conditions.

The density of the natural fibers, cotton and ramie, is about 0.025 g/cm$^3$ higher than for the synthetic cellulosic fibers, staple rayon in particular. No conclusion can be drawn, however, from this known difference alone. To obtain a clearer understanding of the relationships which are involved, an indirect method described below was used.

### *2. Density-Swelling Relationship*

The density-swelling relationship was established by measuring the density of the fibers and their swelling in water. About 80 different cellulosic fibers, mostly synthetic, were measured. The density of a carefully dehydrated sample of fiber was measured by the buoyancy in nonswelling liquids, such as carbon tetrachloride. The fibrous substance was placed in a flask containing carbon tetrachloride and the temperature was very precisely adjusted. The equipment had a built-in micro-balance.

The swelling of the fibers in water was measured gravimetrically. The sample of water-swelled fiber was placed in a screen basket and centrifuged for one minute at a centrifugal acceleration of 750,000 cm/sec$^2$. The centrifuged sample was weighed immediately in a sealed weighing bottle and was then dried to constant weight at 105° to 110°C. The amount of water retained by the centrifuged sample, expressed as a percent of the dry weight, was taken as a measure of swelling.

The values for density and for swelling of commercial synthetic cellulosic fibers did not exhibit great differences. However, inclusion of the results

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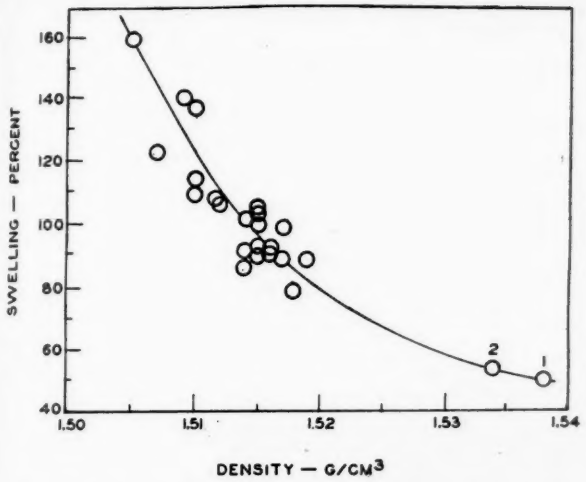


FIG. 1. *Swelling and density of original fibers. The points marked 1 and 2 are for ramie and cotton, respectively, and the other points are for various staple rayons, some with and some without an outer coated layer or skin.*

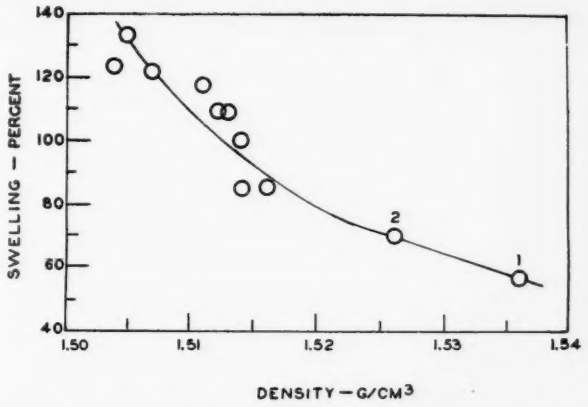


FIG. 2. *Swelling and density of fibers extracted with a 10-percent solution of caustic soda. The points marked 1 and 2 are for ramie and cotton, respectively, and the other points are for various staple rayons, some with and some without an outer coated layer or skin.*

of many experimentally spun fibers provided sufficient differences for the establishment of a definite relationship between density and swelling. This relationship is shown in Figure 1 and includes the results for the natural fibers, cotton and ramie. It is apparent that as the density increases the swelling decreases. This relationship had been predicted from other considerations, but had never been proved. The proof provided by these results should therefore be of special interest.

Fibers of a series of staple rayons were extracted with a 10-percent solution of caustic soda, as is usual in the determination of alkali solubility, and the density and swelling were measured. The relationship between density and swelling of the fibers extracted with the 10-percent solution of caustic soda is shown in Figure 2. The remarkable similarity between the curves of Figures 1 and 2 is apparent.

Experimental fibers which, contrary to expectation, had poor qualities as textile fibers were also measured. It was found that their density was extremely low, the swelling was high, and the wet strength was low. These unusual values were especially conspicuous for a few staple rayons which had an average degree of polymerization higher than is usual. It is not suggested, however, that the high degree of polymerization is the cause for this behavior, since the interrelationships are much more complicated.

Experimental staple rayons were spun which had considerably higher densities, 1.527 g/cm³, than is usual and which had, owing to their basic structure and not because of treatments after spinning, low swelling; a priori considered a desirable quality of commercial fibers. As expected, the swelling was considerably below the usual and amounted to only about 60 percent. In an experiment of the opposite extreme, a viscose staple rayon was spun under otherwise identical conditions except with a density of only 1.499 g/cm³. The swelling of this rayon was very high and was equal to about 140 percent. On the basis of these results, it would seem feasible to spin superior rayon fibers for commercial use which have densities about 0.010 to 0.015 g/cm³ higher than the usual average values of the rayons produced in Germany. However, the practicability of such fibers would have to be based upon the results of actual performance tests.

When various commercial staple rayons were repeatedly dried, it was found that their swelling decreased from about 100 percent to about 65 percent. Simultaneous measurements of density showed an increase with decreased swelling. The final density was about 0.015 g/cm³ higher than the initial density. This indicates that repeated drying can result in a structural change of the fibers, including a reduction in the total internal surface of the fibers.

### *3. Acetylation Technique for Measurement of Radial Density*

A technique was perfected for the measurement of the density of fibers as a function of their radius. In this technique concentric outer layers of the fiber

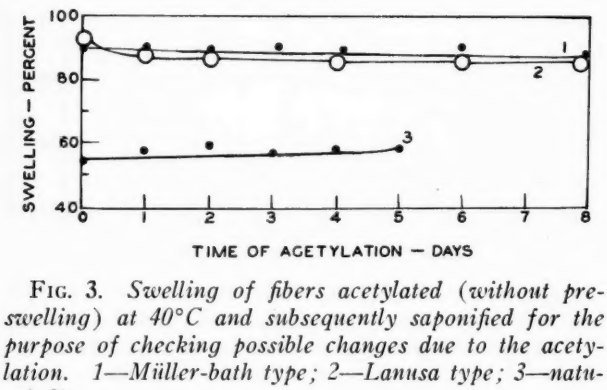


FIG. 3. *Swelling of fibers acetylated (without preswelling) at 40°C and subsequently saponified for the purpose of checking possible changes due to the acetylation. 1—Müller-bath type; 2—Lanusa type; 3—natural fibers.*

were figuratively peeled off in succession as one would peel an onion. The fibers were acetylated for various time intervals and the outer layers of triacetate thus formed in various thicknesses were dissolved and removed with a mixture of 9 parts chloroform and 1 part methyl alcohol. Microscopic examinations showed that in the removal of these layers there was no basic change in the appearance of the fiber core which remained, and the geometrical configuration of the fiber cross section was retained.

In order to explore thoroughly any peculiarities of topochemical acetylation, some fibers were solvent-extracted and acetylated, while others were solvent-extracted, preswelled in water or glacial acetic acid, and then acetylated. Also, since it was desired to study the swelling of the core of the fiber which remained after the acetylated layer was removed, it was essential that the time-controlled topochemical acetylations affect only those outer layers of the fibers which were to be removed. The inner core which remains after the removal of the outer acetylated layer must not be affected. To prove whether these conditions were really accomplished with this acetylation procedure, fibers were acetylated for various time intervals and were then carefully and thoroughly saponified in order to reproduce them in their original state. The regenerated fibers were examined and their density, swelling, and wet strength were measured. The results showed no change from the original fiber. The swellings of the regenerated fibers of three different types, which had been acetylated for various times up to 8 days, are plotted in Figure 3 against time of acetylation. It is apparent that the swelling was not affected by the acetylation and regeneration. The swelling and the density of the fiber core, which remained after 10 to 20 percent of the fiber substance had been acetylated and dissolved off, were determined. The relationship of density to swelling was the same as that shown in Figure 1. This was further evidence that the acetylation technique described did not affect the inner unacetylated fiber core.

The speed of the acetylation process and the thickness of the triacetate layer formed per unit of time vary according to the condition of the original fibers. The speed was substantially greater for fibers which were preswelled in water or glacial acetic acid than for those fibers which were acetylated after mere drying in air. This effect is shown by the results given in Figures 4 and 5, where the amount of substance peeled off (in percent) is plotted against the time of acetylation. The acetylation of the preswelled fibers (Figure 4) was conducted at 20°C and for the air-dried fibers (Figure 5) at 40°C. In the former, only several hours were required for a given amount of acetylation, as compared with several days in the latter. For the preswelled fibers, the Lanusa type were acetylated most rapidly, then the Müller-bath-type (fibers coagulated in an acid bath) and the natural cellulosic fibers. The formalin-treated Müller-bath-type fibers were acetylated at a substantially slower rate. For the air-dry acetylation without preswelling, the natural fibers were acetylated most rapidly, then followed the fibers of the Müller-bath-type, Lanusa type, and finally the formalin-treated Müller-bath-type fibers.

In topochemical acetylation, it is thus possible, after a little practice and using the rates described above, to allow the acetylation to affect only a preassigned outer thickness of the fiber. This control

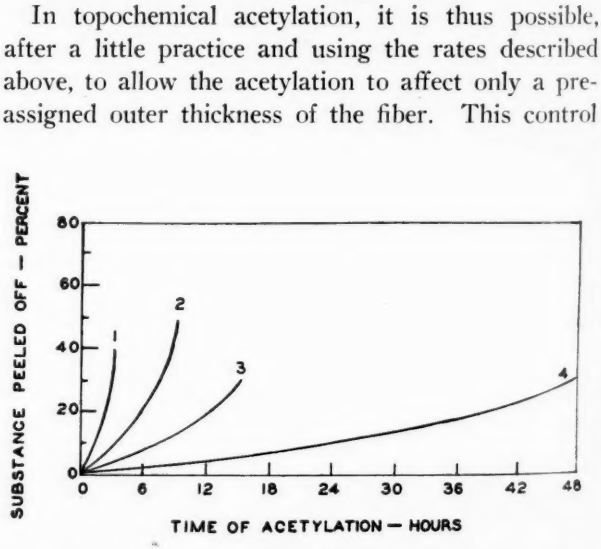


FIG. 4. *Percentage of substance peeled off from fibers acetylated at 20°C after preswelling with water. 1—Lanusa type; 2—Müller-bath type; 3—natural fibers; 4—Müller-bath-type fibers treated with formalin.*

could be easily checked microscopically by dyeing the acetylated fibers with specific acetate dyes. A cross section of such a dyed fiber, when viewed under the microscope, showed clearly demarcated triacetate layers which were approximately circular in shape and could in some cases be separated mechanically from the unacetylated fiber core. The unacetylated core appeared to be surrounded by the dyed, approximately circular, triacetate layer, and could be easily distinguished microscopically.

*4. Application of Acetylation Technique*

Fibers were progressively acetylated for longer and longer periods but under otherwise equal conditions, so that the acetylated outer layer of the fibers, which was dissolved in the solvent and removed, amounted to approximately 5, 10, 15, and so on to 30 percent of the weight of the original fibers. The actual amount of the fiber substance so removed was determined gravimetrically after evaporation of the solvent. The weight of the fiber core which remained after the peeling was used as a check for the amount peeled off. The swelling in water and the density of the original fibers and of the fiber cores, after increasing amounts were peeled off systematically in the described manner, were determined. The results for four types of fibers are given in Figure 6, in which the swelling and density are plotted against the amount of fiber substance peeled off.

It is apparent that cellulosic fibers fall basically into three groups, showing either: (1) a constant radial density, (2) an increase in radial density from the center toward the outside of the fiber, or (3) a decrease in radial density from the center toward the outside of the fiber. The Müller-bath-type fibers, including those treated with formalin, and the natural fibers belong to the second group; viz., they showed a decrease in density from the outside toward the center of the fiber. The Lanusa-type fibers showed in general no change in swelling and density as the acetylation was progressively increased and a greater percentage of fiber substance was peeled off. They belong to the first group, with uniform radial density. Some of these types, however (Cuprama, for example), leaned toward the third group, in which the density increased from the outside toward the center of the fiber.

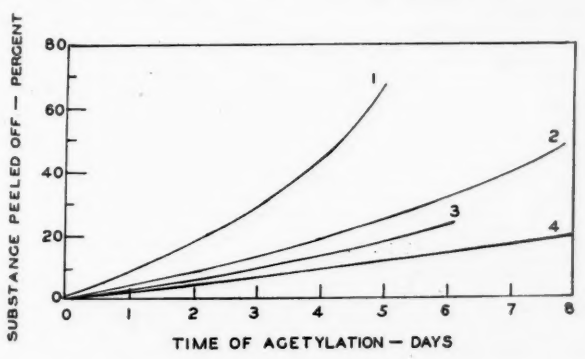


FIG. 5. *Percentage of substance peeled off from air-dried fibers acetylated at 40°C. 1—natural fibers; 2—Müller-bath type; 3—Lanusa type; 4—Müller-bath-type fibers treated with formalin.*

*5. Discussion*

The staple rayons of the Müller-bath type, which showed a higher density near the surface than toward the center, have been characterized from other considerations by Preston, Ohara, Weltzien, and Schrameck as being provided with an "outer coated layer" which is also known as an "outer skin." Weltzien and Schrameck tried to demonstrate the existence of these outer skins by attempting to make them recognizable by dyeing. The results presented in this paper indicate that such a distinct and recognizable outer skin would exist only very rarely. In general, the results show that there is a gradual transition from the densely packed outer layer to the less densely packed layers toward the center of the fiber.

The variation in radial density of the natural cellulosic fibers, cotton and ramie, is basically the same as for the Müller-bath-type rayon fibers. In spite of the establishment of this interesting analogy, the pronounced difference between these two types of fibers must be stressed. It is well known that the swelling of the natural cellulosic fibers is decidedly lower and the density is decidedly higher than for the fibers of the Müller-bath type. The systematic difference of about 0.025 g/cm$^3$ in density (compare curves 1 and 4 in Figure 6) has a pronounced effect on the density of the packing of the structural units in fibers. In addition to this pronounced difference, it is necessary to recognize other differences in the fine structure to explain fully the superiority of cotton. In similar experiments on natural fibers acetylated without preswelling the change in swelling and density was less steep than is shown by curve 4 in Figure 6.

It is evident from the results presented that the higher density of the outer layer of the Müller-bath-

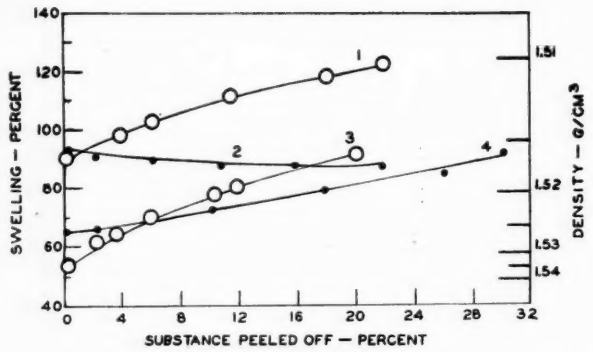


FIG. 6. *Swelling and density of fibers after removal of various amounts of acetylated outer layers. 1—Müller-bath type; 2—Lanusa type; 3—Müller-bath-type fibers treated with formalin; 4—natural fibers.*

type fibers has a pronounced influence on the qualities of the fibers—lower swelling and higher wet strength. The actual density of this outer layer can be computed from the data. For many fibers of this type this density lies between about 1.580 and 1.600 g/cm³ and therefore closely approaches the theoretical density of cellulose and cellulose hydrate.

An attempt was made to determine the tensile strength of the fiber core which remained after the acetylated layers were removed. This work was extremely tedious and the results are insufficient to be conclusive. However, it could be shown in several cases that the tensile strength, especially the wet tensile strength, decreased decidedly after the outer layers were peeled off.

As has already been stated, the relationship between swelling and density when 10 to 20 percent of fiber substance was peeled off was the same as that shown in Figure 1. Also no basic change in the appearance of the fiber core was evident microscopically when the outer layers were systematically peeled off in increasing amounts. In a few instances, fibrillar splitting was observed, indicating that such fibers are inhomogeneous with respect to density in the fiber cross section. Franz, Eisenhut, and others, in their work on "squeeze-photography" of fibers, also observed fibrillar splitting.

Anisotropic longitudinal swelling was found for several rayon fibers between their original state and after about 20 percent of fiber substance was peeled off. The longitudinal swelling was measured micrometrically. The swelling of the fiber core was greater than for the whole fiber. This indicates that after the removal of the denser outer layer, the fiber core could swell more freely. The reverse was found for the Cuprama fiber, in which the fiber core showed a lower lengthwise swelling than the original whole fiber. This reverse condition can be attributed to the higher density of the fiber core and the lower density of the outer layer previously referred to (curve 2 in Figure 6).

X-ray investigations in cooperation with Dr. H. Zahn showed that the orientation in the fiber core of the Müller-bath type, when about 20 percent of the outer fiber substance had been peeled off, was somewhat smaller than for the whole fiber. The differences were too small, however, to permit drawing final conclusions. Double-refraction measurements had not been made but were contemplated.

The measurements on the formalin-treated fibers (curve 3 in Figure 6) showed basically nothing new, except that the swelling was considerably lower than for the untreated fibers (curve 1 in Figure 6).

The experiments made to date on various cellulose hydrate rayons show practically the same relationships as have been discussed for staple rayons. The densities of the rayons, determined under identical conditions, are lower than those for the staple rayons.

It should be noted that W. Moll found a change in the density and swelling by heating staple rayons. He did not obtain similar changes on dry fibers treated with liquid ammonia to decrease their swelling. A relationship between density and degree of polymerization of staple rayon is not to be expected without taking into consideration certain aspects in the spinning of viscoses with a high degree of polymerization, which are not yet generally known. The relationships are such, even under the present general spinning methods, that the density of staple rayon with a high degree of polymerization is lower than the average value for commercial staple rayons. From the many experiments which have been made, it does not follow in general that fibers with a denser outer layer have a lower density than the fibers without this layer. The relationships are much more complicated. Also the relationship between concentration of viscose solutions and density of staple rayon, proposed by W. Moll, is in need of modification.

### 6. *Acknowledgment*

The assistance of John Krasny and Miss Josephine Blandford with the translation and the preparation of the figures is gratefully acknowledged.

## III. List of Papers Published by Professor Egon Elöd and Staff Since 1941 (SKL–1001) *

*1941*

1. EE, HN, und HZ: Zur Kenntnis der Reaktionsfähigkeit der Wolle (Reactivity of Wool). *Melliand Textilber.* **22**, 76.
2. EE, HN, und HZ: Über den Aufbau der Wolle und deren Reaktionsfähigkeit (Structure and Reactivity of Wool). *Kolloid-Z.* **95**, 81.
3. EE: Zur Kenntnis der Wollfaser (A Study of Wool Fiber). *Kolloid-Z.* **96**, 284.
4. HZ: Übermikroskopische Aufnahmen von isolierten Spindelzellen der Schafwolle I (Electron-microscopic Study of Isolated Spindle Cells from Sheep Wool, I). *Melliand Textilber.* **22**, 305.
5. EE, HN, und HZ: Über die Einlagerung von Schwermetallsulfiden in Keratinfasern (Deposition of Heavy Metal Sulfides in Keratin Fibers). *Ber. Deutschen Chem. Ges.* **74**, 1759.
6. HZ: Strukturuntersuchungen an Faserkeratinen (Structural Studies of Fibrous Keratins). *Naturwissenschaften* **29**, 591.

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7. EE, HN, und HZ: Die Einwirkung von Sodalösung auf Wolle (Action of Sodium Carbonate Solution on Wool). *Melliand Textilber.* **23**, 58.
8. EE und TS: Über das Verhalten von Polyamiden beim Färben (Dyeing Behavior of Polyamides). *Melliand Textilber.* **23**, 437.
9. HN und HZ: Über die Feinstruktur von Wollkeratin (Fine Structure of Wool Keratin). *Zeit. physik. Chem.* (*B*) **51**, 265.
10. EE, HN, und HZ: Die Einwirkung von Wasserstoffperoxyd auf Wolle (Action of Hydrogen Peroxide on Wool). *Melliand Textilber.* **23**, 313.
11. HZ: Übermikroskopische Aufnahmen von isolierten Spindelzellen der Schafwolle II (Electron-microscopic Study of Isolated Spindle Cells from Sheep Wool, II). *Melliand Textilber.* **23**, 157.
12. EE, HN, und HZ: Über den Zusammenhang zwischen Schädigung und Cystingehalt der Wollfaser (Relation Between Cystine Content and Damage to Wool Fibers). *Klepzigs Textil-Z.* **45**, 663.
13. EE, HN, und HZ: Struktur und Reaktionsfähigkeit der Wollfaser (Structure and Reactivity of the Wool Fiber). *Kolloid-Z.* **100**, 393.
14. EE, HN, und HZ: Über die Einwirkung von Salzäuer auf das Wollkeratin (Action of Hydrochloric Acid on Wool Keratin). *Melliand Textilber.* **23**, 577.

*1943*

15. HZ: Über thermisch verkürzte Keratinfasern (Keratin Fibers Shortened by Heat). *Naturwissenschaften* **31**, 137.
16. HZ: Übermikroskopische Aufnahmen von isolierten Schuppenzellen der Schafwolle (Electron-microscopic Study of Isolated Scale Cells of Sheep Wool). *Melliand Textilber.* **24**, 157.
17. EE, HN, und HZ: Gewinnung und Eigenschaften von Wollspindelzellen (Preparation and Properties of Wool Spindle Cells). *Melliand Textilber.* **24**, 245.
18. HN und HZ: Zum Aufbau der Faserproteine (Structure of Fibrous Proteins). *Zeit. physik. Chem.* **192**, 333.
19. HZ: Röntgenographie der Schafwolle (X-Ray Photography of Sheep Wool). "Kolloidchemisches Taschenbuch," 2 (1943 Edition), 150.

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20. EE, HN, und HZ: Zur Kenntnis der Hitzeschrumpfung von Keratinfasern (Thermal Shrinking of Keratin Fibers). *Melliand Textilber.* **25**, 73.
21. EE und HZ: Über die Einwirkung von Formamid auf Keratine (Action of Formamide on Keratins). *Kolloid-Z.* **108**, 94.
22. EE und HZ: Über die Einwirkung von Pankreatin auf Faserkeratine I (Action of Pancreatin on Fibrous Keratins, I). *Melliand Textilber.* **25**, 361.
23. EE und TS: Über das Verhalten von Polyamiden beim Färben: II. Mitteilung (Dyeing Behavior of Polyamides, Part II). *Melliand Textilber.* **25**, 237.
24. EE und TS: Über das Verhalten der Polyamide beim Färben: III. Mitteilung (Dyeing Behavior of Polyamides, Part III). *Melliand Textilber.* **25**, 309.

*1945*

25. EE und HGF: Zur Kenntnis der Quellung der Zellwolle * (A Study of the Swelling of Staple Fiber). (This manuscript was given to the editor of *Kolloid-Zeitschrift.*)
26. EE und HGF: Einfluss der Faserstruktur der Zellwollen auf ihre Quellung † (Influence of the Fiber Structure of Staple Fibers on Their Swelling Behavior).

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* Authors in this list are designated by initials. EE is Egon Elöd. HZ is H. Zahn. HN is H. Nowotny. TS is Th. Schachowskoy. HGF is H. G. Fröhlich. (Titles were translated by Julian F. Smith.)

* NOTE: This manuscript may be one of those promised by the editor of *Kolloid-Zeitschrift* to the occupation authorities, or it may be one of those which was lost.—J. F. S.

† NOTE: This manuscript was given to the editor of *Melliand Textilberichte.* A translation of it is given in Part II of this report.

# An Approximate Function for Testing the Significance of Differences According to the "Student"-Fisher *t*-Test

**W. James Lyons** *

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*The method proposed in the following paper has been deemed by its reviewers to be suitable for adoption by industrial research laboratories. Although it was not designed specifically for textile applications, in view of the fact that statistical methods are used to a greater or lesser extent in textile laboratories, it would appear that this method should be of interest to textile research personnel.*

IN testing the significance of mean differences and differences between means, according to Fisher's adaptation of "Student's" method, it is customary practice to compare the $t$ values calculated from the observed data with the $t$ values for a normal population as given in published tables. In these tables, which follow the form used by Fisher [1], the critical values of $t$ corresponding to selected probabilities that larger absolute values of $t$ will be found are given for successive degrees of freedom. A judgment as to whether the statistic under test is or is not significant is then made and reported.

One of several minor disadvantages in this procedure is the necessity for having at hand a copy of the table of $t$ values when a significance test is being made. A more serious defect is the lack of provision for simply and concisely reporting the results of the significance test to readers not well versed in statistical theory. It is, of course, possible for the experimenter merely to state that the mean or difference is "not significant," "significant," or "highly significant," but this limits discretion in judging the results to the experimenter. In many cases, the reader of a technical article or the director of research to whom reports are made desires to see the quantitative evidence upon which conclusions are based. The $t$ calculated from the experimental data is such a criterion, but to be of much utility it must be accompanied by critical $t$ values, taken from tables, for the number of degrees of freedom nearest that in the particular experiment and at the relevant levels of significance. Assuming that the reader has at least a general familiarity with the $t$-test, he then has the task of comparing the $t$ from experiment with the critical values. While thorough, this procedure becomes tedious, if not confusing, when many pages of data and analyses are involved.

Evidently, it would be desirable to have available a simple function involving the statistic under test and some estimate of its error, such that the value of the function would readily indicate, without necessary recourse to tables, whether the statistic is significant. Preferably the critical value of the function should be either unity or zero [2].* It is imperative that the function, for practicality, contain a small number of constant coefficients (two are involved in the function introduced here).

### Definition of the $\Psi$ Function

These requirements are met by a significance function which adapts the principle of the familiar $t$-test and has the general form:

$$\Psi = t - t_c, \qquad (1)$$

where $t$ is the ratio $\left|\frac{\bar{x} - \mu}{s_{\bar{x}}}\right|$, $\bar{x}$ being the mean of a

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† Administered by the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

* Harold Jeffreys discusses a function $K$ which he has introduced, this function being such that for $K > 1$ the *null hypothesis* is supported, while for $K < 1$ the hypothesis is subject to rejection; at $K = 1$ the test is inconclusive.

TABLE I

| Level | $a_i$ | $b_i$ |
|---|---|---|
| 5% | 1.957 | 2.73 |
| 2% | 2.320 | 4.44 |
| 1% | 2.565 | 6.00 |

sample of $n$ observations, $\mu$ the mean of the parent population or an assumed value, $s_{\bar{x}}$ the estimated standard deviation of the mean, and $t_c$ is the critical value of $t$ for the particular case. In the familiar usage of the $t$-test, the value of $\bar{x} - \mu$ is regarded as possessing a certain level of significance if the $t$ from the experimental data, $\left|\frac{\bar{x} - \mu}{s_{\bar{x}}}\right|$, exceeds the tabulated, critical value $t_c$ for that level. Reflecting this criterion, the test introduced here requires that the significance function for the $i$-percent level, $\Psi_i$, be greater than zero. For $\Psi_i < 0$, the value of the statistic has a lower level of significance.

Unfortunately, the *rigorous* calculation of the $t_c$ values for various degrees of freedom, at the different levels of significance, is complicated and time-consuming. In the tables of critical $t$ values it is evident, however, that $t_c$ at a particular significance level is a function of the number of degrees of freedom, $f$. Exploiting this observation, it has been found possible, when $f$ is not too small, to reproduce the tabulated values of $t_c$ to a good approximation with the relation

$$t_c \approx t_i(f) = a_i + \frac{b_i}{f}, \qquad (2)$$

where $a_i$ and $b_i$ are empirical constants having unique values for any given level of significance. The values of these constants for the three levels most commonly considered are given in Table I. The value of $a_i$ and $b_i$ were determined by the method of least squares using the critical values $t_c$, as tabulated by Fisher [1], Snedecor [3], and Goulden [4] for various levels of significance.

The significance function may now be written in full,

$$\Psi_i = \left|\frac{\bar{x} - \mu}{s_{\bar{x}}}\right| - a_i - \frac{b_i}{f}, \qquad (3)$$

where $i$ denotes the level of significance in percentage at which it is desired to test the data of experiment. If for $\Psi_5 > 0$ the statistic under test is regarded as being "significant," then for $\Psi_2 > 0$, it may be regarded as "very significant," and for $\Psi_1 > 0$, "highly significant"; while for $\Psi_5 < 0$, no significance is to be attached to the statistic. Evidently, $\Psi_1 < \Psi_2 < \Psi_5$ for a particular set of data.

TABLE II

| | 5% level | | 2% level | | 1% level | |
|---|---|---|---|---|---|---|
| $f$ | $t_i$ | $t_c$ | $t_i$ | $t_c$ | $t_i$ | $t_c$ |
| 1 | 4.687 | 12.706 | 6.760 | 31.821 | 8.565 | 63.657 |
| 5 | 2.503 | 2.571 | 3.208 | 3.365 | 3.765 | 4.032 |
| 7 | 2.347 | 2.365 | 2.954 | 2.998 | 3.422 | 3.499 |
| 9 | 2.260 | 2.262 | 2.813 | 2.821 | 3.232 | 3.250 |
| 10 | 2.230 | 2.228 | 2.764 | 2.764 | 3.165 | 3.169 |
| 15 | 2.139 | 2.131 | 2.616 | 2.602 | 2.965 | 2.947 |
| 20 | 2.093 | 2.086 | 2.542 | 2.528 | 2.865 | 2.845 |
| 25 | 2.066 | 2.060 | 2.498 | 2.485 | 2.805 | 2.787 |
| 30 | 2.048 | 2.042 | 2.468 | 2.457 | 2.765 | 2.750 |
| 40 | 2.025 | 2.021 | 2.431 | 2.42* | 2.715 | 2.704 |
| 50 | 2.012 | 2.008 | 2.409 | 2.40 | 2.685 | 2.678 |
| 60 | 2.003 | 2.000 | 2.394 | 2.39 | 2.665 | 2.660 |
| 70 | 1.996 | 1.994 | 2.383 | 2.38 | 2.651 | 2.648 |
| 80 | 1.991 | 1.990 | 2.376 | 2.38 | 2.640 | 2.638 |
| 90 | 1.987 | 1.987 | 2.369 | 2.37 | 2.632 | 2.632 |
| 100 | 1.984 | 1.984 | 2.364 | 2.36 | 2.625 | 2.626 |
| 1000 | 1.960 | 1.962 | 2.324 | 2.33 | 2.571 | 2.581 |
| $\infty$ | 1.957 | 1.960 | 2.320 | 2.326 | 2.565 | 2.576 |

* Values of $t_c$ at the 2 percent level for $f \geqslant 40$ are taken from Goulden [3], who gives values to only the second decimal place.

## Discussion

The adequacy of the function $\Psi$ as a means of applying the $t$-test in a new manner may be judged by a comparison of $t_i$ with the corresponding $t_c$. This has been done in Table II for various degrees of freedom and levels of significance. The values of $t_c$ given in the table are taken from the published tables previously mentioned [1, 3, 4].

Examination of Table II reveals that while differences between $t_i$ and $t_c$ occur, these are negligibly small for $f \geqslant 9$. The maximum error due to the use of $t_i$ is found to be a shift of the nominal 1% level to 0.95%, the 2% level to 1.95%, and the 5% level to 4.95%. The differences become appreciably larger as $f \to 1$, so that the present $\Psi$-function test is not applicable to samples for which $f < 9$. This restriction, however, does not reduce the utility of the $\Psi$-function in any important way, since the $t$-test itself is highly inadequate when applied to samples involving less than 10 observations, no other information being available [5]. Many research and technical workers, without depending on such rigorous considerations, have refrained on general grounds from applying significance tests to samples of less than 10 observations.

The small error introduced in $\Psi$ at certain values of $f > 9$ is inconsequential. In the most unfavorable case, it is possible for $\Psi$ calculated using $t_i$ to

be in error by $-0.02$ as compared with the $\Psi$ calculated using $t_c$ given in the quoted tables of Fisher, *et al.* When $\Psi$ is small, as occurs when the experimental $t$ is near the critical value, an error of $-0.02$ may appear to be important. But a value of $\Psi$ so small as to be affected in sign by an error of $\pm 0.02$ is in any case to be regarded as inconclusive as concerns significance. A test at a lower level or dditional experimental data are called for.

Evidently, another function could be readily found such that it would yield values closely duplicating the values of $t_c$ for the range $0 < f < 9$. The question of the competence of the "Student"-Fisher test in this range of $f$, however, discourages this procedure.

**Acknowledgment**

The writer is indebted to Dr. Carl M. Conrad and A. Mason DuPré, Jr., of the Southern Regional Research Laboratory, for their interest and helpful suggestions in the preparation of this note.

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# Color Measurements of Standards for Grades of Cotton

**Dorothy Nickerson***

*Measurements of the color of standards for grades of cotton, which were made in the United States Department of Agriculture, are shown in a series of diagrams. These illustrate the relation of the grades to each other in color, how the color may change during a period of years, and color measurements of the original standards, copies of them, and of the standards adopted in 1946 to become effective August 1, 1947.*

## Method Used for Color Specification and Measurement

Measurement of color of raw cotton began in the United States Department of Agriculture in 1927. Early in the work the Munsell color notation [1] was adopted as a means of specification since by means of its tridimensional concept color may be described in scales of hue, value, and chroma. In each of these scales the steps are visually equidistantly spaced. As a consequence, the intelligent layman may interpret the colorimetric results expressed in these terms quite as easily as the color-trained expert.

Disc colorimetry was adopted as a simple and rapid means of measurement, special instruments being devised for work with agricultural products [2]. The first instrument, built by Keuffel and Esser for the purpose of measuring the color of raw cotton, is still in use. Many operating improvements have been made—in fact, the Bausch and Lomb Optical Company has since made a more compact model for measuring other products—but this first instrument is the one on which all measurements here reported have been made. It is the instrument shown in Figure 1.

Much work has been done in the measurement and standardization of the Munsell system since 1927, as a result of which it is now practical to translate from one set of standard color terms to another. The chief publications on this subject appeared in 1940 and 1943 in the *Journal of the Optical Society of America*. These were followed in 1946 by publication of a handbook on the method of disc colorimetry [3].

In the cotton work the method of measurement followed is that described in the handbook [3] under "Early Method." Since the work was initiated prior to publication of the 1929 *Book of Color* [4], the discs used are Munsell Atlas papers on which spectrophotometric records have been made. Since conversion tables based on these discs were prepared early in the work, and since many measurements were already made before the adoption and use of the 1931 internationally standardized I.C.I. method and its application to additive formulas for use with the disc method, the early method is still used for cotton work. An additional reason for nonconversion through I.C.I. data is that the illuminant in the disc colorimeter used for cotton is about 4520°K [5] (400-watt projection lamp operated at 105V, average 2900°K, plus 3.6 mm. Corning Daylite of December 21, 1926, melt). Since color transformations and reference data are usually made in terms of "C" illuminant (about 6750°K), it has not seemed that conversion to terms of "C" illuminant would yield better information than the method as now used. The scales on which the data are plotted are therefore on a relative instead of an absolute basis.

## History and Description of Standards for Grades of Cotton

Cotton quality is defined as the physical properties or attributes of cotton which affect its usefulness. Some of these properties or attributes are included in the standards for grade and staple [6]. Standards for grade are those with which the color laboratory is concerned.

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The first U. S. grades for American upland cotton were authorized by the 1909 appropriation act for the Department of Agriculture. That act directed the Secretary of Agriculture to establish 9 white grades (permissive) and to prepare practical forms of them. In 1914 the Cotton Futures Act was passed which made the use of standards for grade mandatory for delivery of cotton on futures contracts. In 1918 official grades were established for American-Egyptian cottons. In 1923 the U. S. Cotton Standards Act was passed, and the first international conference held at which U. S. standards for grade of American upland cotton were agreed upon and accepted by all of the leading European cotton exchanges. These standards have since been referred to as the universal standards for American cotton. Except for the establishment of 5 grades of Extra White cotton, these standards remained as promulgated on July 20, 1923, until a general revision was approved in August, 1935. After 1923, international grade standards conferences were held every 2 years until 1935, when copies of a revised set were taken to Havre for consideration by the European delegates, who later (1936) came to the United States to approve copies of this revised set. Color measurements of the 1932, 1933, and 1934 cotton crops, and a market survey in 1934, were made and used in revising the standards in 1935 [7]. After 1936, conferences were to be held every 3 years, but the war intervened, and the 1939 conference was the last until the spring of 1946.

U. S. Standards for the grade of American upland cotton, known as Universal Standards [7], are accepted and used the world over. Their use is mandatory in this country for the sale of cotton unless it is sold on private type or actual samples. The standards are put up in black boxes, 12 samples to a box, 20-by-20 inches, as illustrated in Figure 1, each box representing the range of color, leaf, and preparation within a single grade. A photograph of the cotton in the box is inserted inside the cover of each box to verify the preparation of the cotton and the position of the foreign matter. Copies of the standards are sold for use in the cotton industry.

In the grading of American cotton both major and minor color differences are taken into consideration. The major differences are those between the classes of Extra White, White, Spotted, Tinged, Yellow Stained, and Gray, the color differences being chiefly those of chroma. The Gray and Extra White grades contain little chroma as compared with that shown by the increasing degree of yellowness in the White, Spotted, Tinged, and Yellow Stained grades. Until 1935 a class of Blue Stained cottons was also included. The minor differences are those which occur between grades of any single color class, as between Middling and Strict Middling White grades, or within single grades, as the difference between the brightest and the dullest samples of Strict Low Middling White. Since it is the policy of the United States Department of Agriculture to designate grades of agricultural products by number, the cotton grades have numbers as well as names: No. 1 is Middling Fair, the highest grade; No. 9 is Good Ordinary, the lowest grade for which there is a standard. Years ago, when the first cotton grades were established in the Liverpool market, the term "Middling" was used for the middle grade. Today, the term is still used for the base grade.

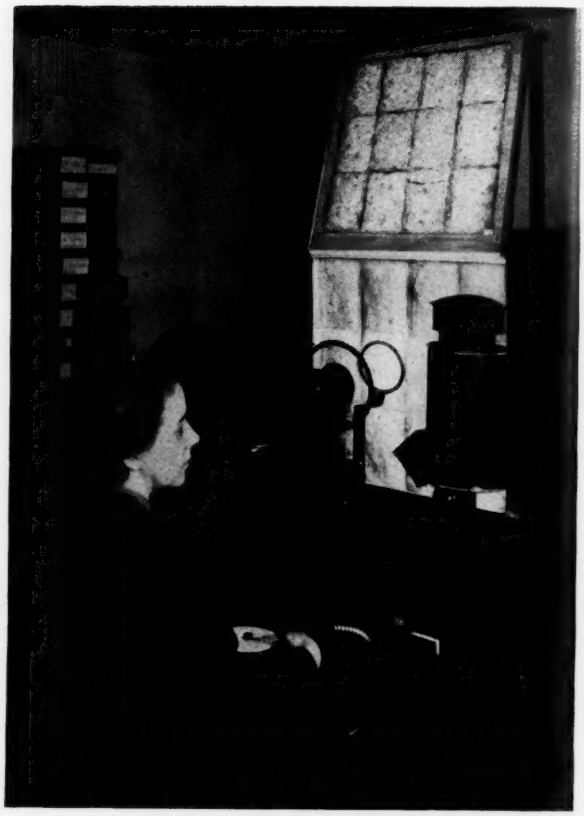

FIG. 1. *Disc colorimeter used for measuring standards for grades of cotton. An area 4 inches in diameter behind the black ring is measured. The color measured is the average of the fiber color, leaf color, and preparation as these three grade factors are combined in the sample behind the black ring.*

For the 1923–1935 period standards for grade were as listed in Table I. Of these, 25 were represented

TABLE I. OFFICIAL STANDARDS FOR GRADE OF AMERICAN UPLAND COTTON (STATUS IN MARCH, 1933) (THOSE REPRESENTED BY PHYSICAL STANDARDS IN ROMAN; DESCRIPTIVE GRADES IN ITALIC TYPE)

| Grade No. | Symbol * | Color Class: Blue Stained | Gray | Extra White † | White | Spotted | Yellow Tinged | Light Stained | Yellow Stained |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MF | | | | 1 | | | | |
| 2 | SGM | | | | 2 | *2 Sp* | 2 YT | | |
| 3 | GM | 3 B | *3 Gr* | 3 EW | 3 | *3 Sp* | 3 YT | *3 LYS* | 3 YS |
| 4 | SM | 4 B | *4 Gr* | 4 EW | 4 | *4 Sp* | 4 YT | *4 LYS* | 4 YS |
| 5 | M | 5 B | *5 Gr* | 5 EW | 5 | *5 Sp* | 5 YT | *5 LYS* | 5 YS |
| 6 | SLM | | | 6 EW | 6 | *6 Sp* | 6 YT | | |
| 7 | LM | | | 7 EW | 7 | *7 Sp* | 7 YT | | |
| 8 | SGO | | | | 8 | | | | |
| 9 | GO | | | | 9 | | | | |

* M for Middling, F for Fair, S for Strict, G for Good, L for Low, O for Ordinary.

† Extra White grades, while a part of U. S. official grades, are not a part of the Universal grade standards, as are all other grades listed.

in physical form by boxes similar to the one which holds the sample in Figure 1; 13 were descriptive. In 1935, effective 1936 to date, the standards were revised as listed in Table II. The total number of standards for grade was reduced to 32, physical standards being reduced to 13.

In 1946 the standards were again revised, to become effective August 1, 1947. The grades remain as listed in Table II with the one addition of a descriptive grade for Strict Low Middling Gray (6 Gr).

The method of preparing grade standards in physical form in the United States Department of Agriculture is that the delegates to the international conference agree on a set of boxes of type samples to represent the standards, then examine, at a conference called for the purpose, enough duplicate sets to supply one or more to each organization that is a party to the international agreements. In the interim between conferences, the preparation of boxes of standards is continuous in order to supply sets for current purchase requests. They are prepared (and passed) in a specially lighted classing room.

TABLE II. OFFICIAL STANDARDS FOR GRADE OF AMERICAN UPLAND COTTON, EFFECTIVE 1936–1946 (PHYSICAL STANDARDS IN ROMAN, DESCRIPTIVE STANDARDS IN ITALIC TYPE)

| Grade No. | Color Class: Gray | Extra White | White | Spotted | Tinged | Yellow Stained |
|---|---|---|---|---|---|---|
| 1 | | | *1* | | | |
| 2 | | | 2 | | | |
| 3 | *3 Gr* | *3 EW* | 3 | *3 Sp* | 3 T | *3 YS* |
| 4 | *4 Gr* | *4 EW* | 4 | *4 Sp* | 4 T | *4 YS* |
| 5 | *5 Gr* | *5 EW* | 5 | *5 Sp* | 5 T | *5 YS* |
| 6 | | *6 EW* | 6 | *6 Sp* | 6 T | |
| 7 | | *7 EW* | 7 | *7 Sp* | 7 T | |
| 8 | | *8 EW* | 8 | | | |
| 9 | | *9 EW* | 9 | | | |

At each conference one set of boxes out of all sets passed is selected by lot, and is sealed and deposited in a vault, to remain unopened until the next conference. It was generally assumed that copies so selected would, when opened, satisfactorily represent the original standards which all copies are intended to represent. By 1933 the copies being made to represent the 1923 originals were considered nonrepresentative of the crop; but while it was known that the 1923 original set had itself changed very considerably, it was not suggested that copies might also drift off year by year. Instead it was widely assumed that the color of the crop had changed so that it no longer provided the deep creamy colors now shown by the standards, particularly by the upper grades. Therefore, in 1935, after extensive surveys of cottons in the market and in current crops, new standards were adopted, effective in 1936.

## Color Measurements Relating to Standards for Grade

By 1936 the work of the color laboratory was well established. Measurements had been made of the old standards, and of current standards. Beginning in 1932 surveys were made of the color of current crops. In 1932 about 3,000 samples were measured for this purpose, in 1933 and 1934 over 10,000.

Statistical analysis by methods of multiple curvilinear correlations used early in the cotton work showed that in the 9 grades of the white standards the correlation of three color factors and grade was 0.981 for the earliest measured standards (1928), 0.985 for 1936 copies of the new standards. Since two of the three color factors, value and chroma, accounted for practically all of this relationship, color

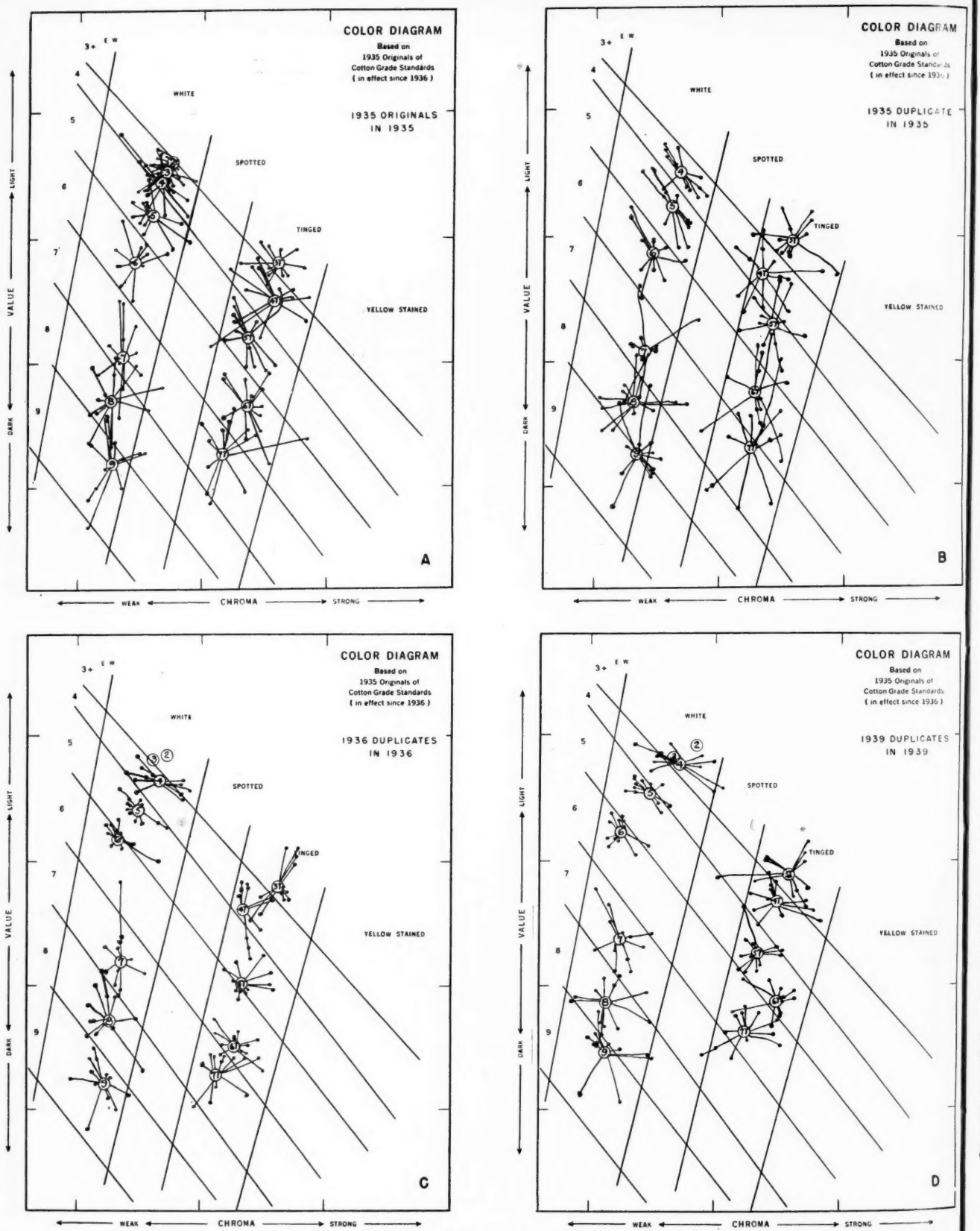


FIG. 2. *Diagrams of color of four copies of the standards based on the 1935 original set and measured in the year each was put up. A—1935 original standards in 1935. B—1935 duplicate in 1935. C—1936 duplicates in 1936. D—1939 duplicates in 1939.*

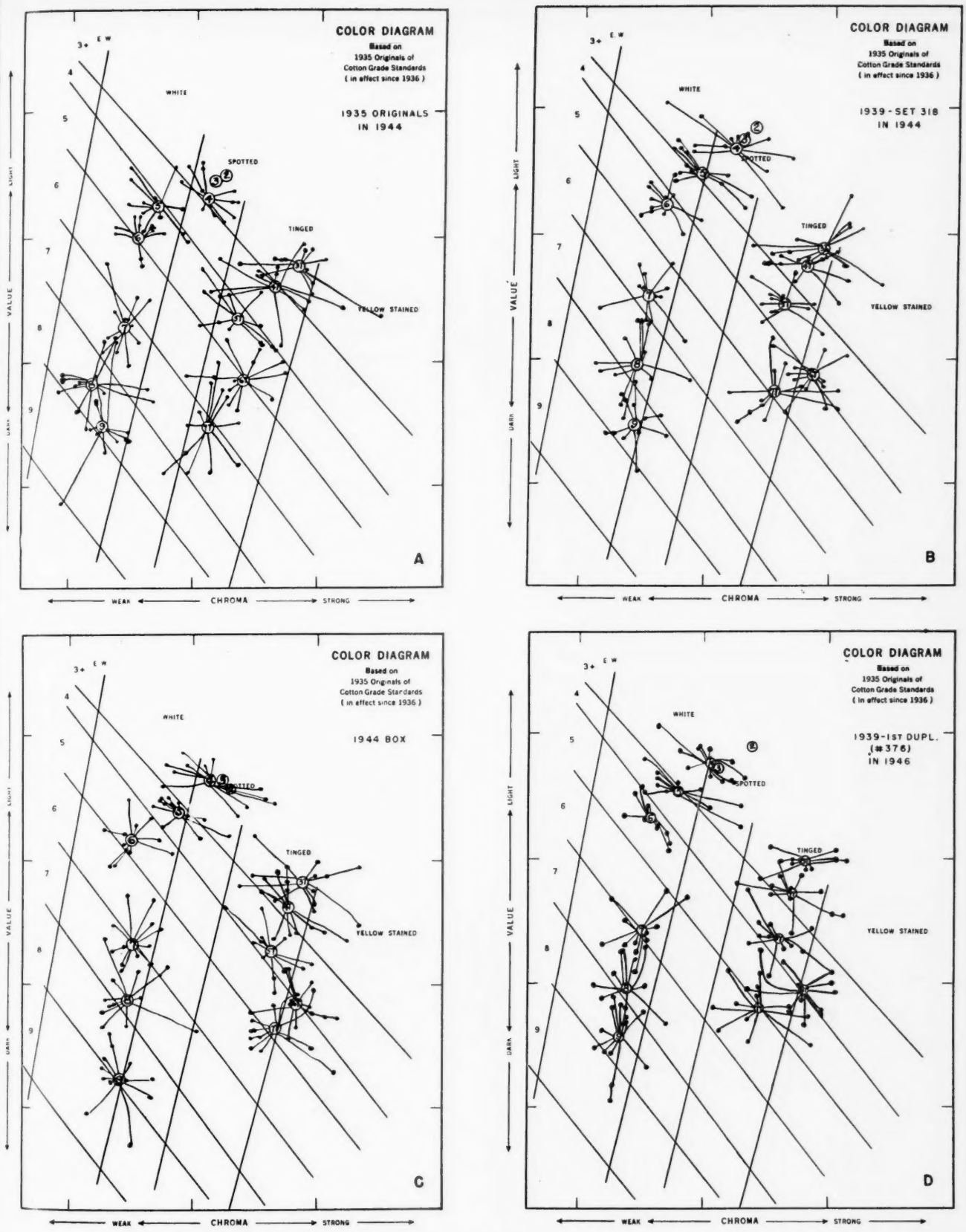


FIG. 3. *Diagrams of color of recent measurements of four copies of the standards based on the 1935 original set. A—1935 original standards in 1944. B—1939 duplicate in 1944. C—1944 copy of 1939 duplicates, in 1944 D—1939 first reserve set opened at the 1946 conference.*

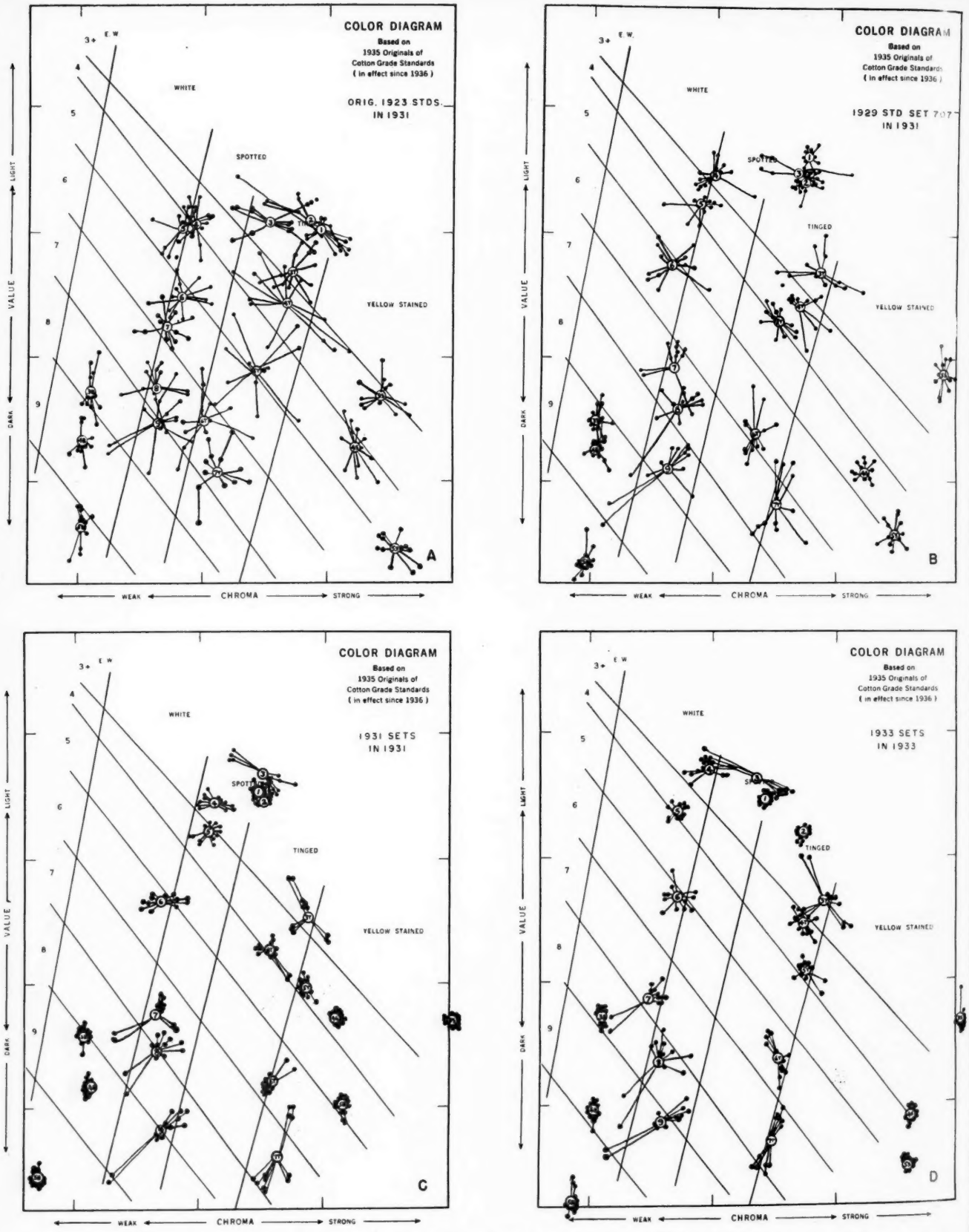


FIG. 4. *Diagrams of color of four copies of the standards based on the 1923 original set. A—1923 original standards as measured in 1931. B—1929 duplicate measured in 1931. C—1931 duplicates measured in 1931. D—1933 duplicates measured in 1933.*

charts for cotton have since been plotted to show value vertically, chroma horizontally.

Measurements of the original 1935 standards, as sent to Havre and agreed upon there, were made in 1935. In order to have a grade diagram to which all color data might be referred, the 1935 originals were used as the basis for the diagonal network on the background of all the diagrams in Figures 2–7.

These diagrams put on record the color relations of grades within each set of standards shown, and make possible a comparison of the several sets.

Figure 2 includes diagrams of the color of standards for grade, measured in the year each set was put up: A—1935 original standards in 1935; B—1935 duplicate in 1935; C—1936 duplicates in 1936; D—1939 duplicates in 1939.

Figure 3 includes diagrams of more recent measurements: A—1935 original standards in 1944; B—1939 duplicate in 1944; C—1944 copy of 1939 duplicates, in 1944; D—1939 first reserve set opened at the 1946 conference, measured in 1946.

For purposes of comparison, Figure 4 includes diagrams of four sets of standards based on the 1923 original set: A—1923 original standards as measured in 1931; B—1929 duplicate measured in 1931; C—1931 duplicates measured in 1931; D—1933 duplicates measured in 1933.

All the information, with the exception of the measurements shown in Figure 3D, was available when it became necessary to prepare copies of the standards for the first postwar international cotton-grade conference. The 1935 originals had changed too much by then to represent the original standards as and when established in 1935; the 1939 duplicates had also changed too much to consider their use. When conferences were held at 2- or 3-year intervals the change from the duplicate against which they were previously matched was slight, and those in charge of the preparation of the cotton standards were able to make slight adjustments in color of new duplicate sets as far back toward the original standards as they thought necessary. In the 7-year interval between the 1939 and 1946 conferences, changes in the standards were too great to be rectified by slight adjustments. By 1946 it was also very difficult to find cotton, except from very old stock, that could be used in preparing copies of the 1939 duplicates. Already there had been an upward drift in the standards since 1935. In fact, the situation was almost identical with that in 1935 when it became

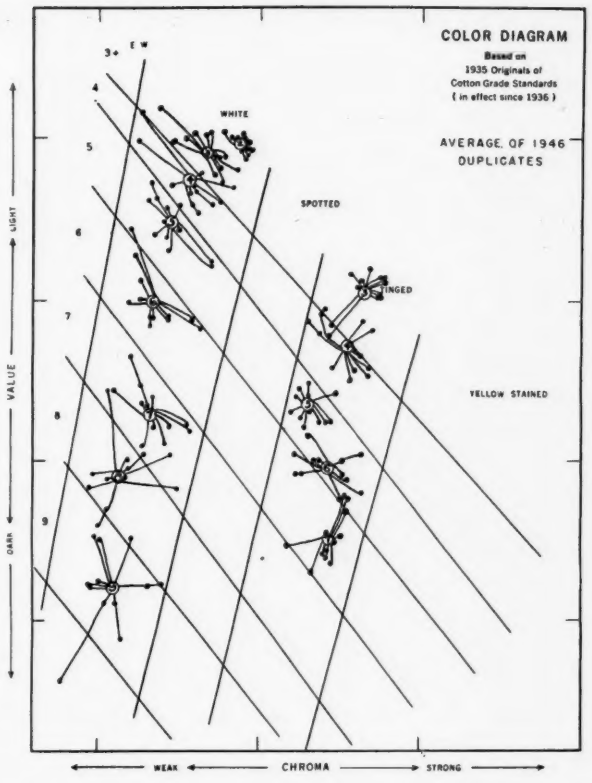


FIG. 5. *Diagram of color of standards as passed at 1946 conference as new standards.*

necessary to depart from copying the 1933 duplicates of the 1923 standards.

It was decided, therefore, in spite of the considerable change necessary to bring the 1946 copies back to the original color of the 1935 standards, that this change should be made. Although the intent was to continue the use of the 1935 standards, as and when established, it was realized that to many of those who would attend the conference the 1946 copies would appear to be new standards. The signatory groups were therefore requested to come to the conference prepared to consider the 1946 boxes as new standards.

Measurements of these new standards, presented to the 1946 conference and adopted by it, are shown in Figure 5. Comparison of this set with the sets shown in Figures 2 and 3 indicates that the 1946 standards, particularly the white grades, are closer to the 1935 original standards than to any other set. This means that the 1946 standards which will become mandatory for use August 1, 1947, although differing in color from 1939 copies of the 1935 standards, are close to the color level of the 1935 origi-

nals. For factors other than color, no changes were necessary.

For comparison of the color of the standard with the color of current crops, the results of surveys for the 1944 and 1945 crops are shown in Figure 6. The color of these recent crops is not significantly different from that of the 1933 and 1934 crops for which measurements were available and considered when the 1935 original standards for grade were adopted.

The color of the crop from different areas in the Cotton Belt varies about as shown in Figure 7. Cottons from the southeastern area are usually of average whiteness; those from the south central area, including the Mississippi Delta and Arkansas region, tend toward the white or gray side of the chart; cottons from the southwest area, including Texas and Oklahoma, tend to have more chroma; those from the western area, which includes California, Arizona, New Mexico, and west Texas, not only tend toward the white or gray side of the chart but are also bright as well, crowding the upper-left corner of the chart.

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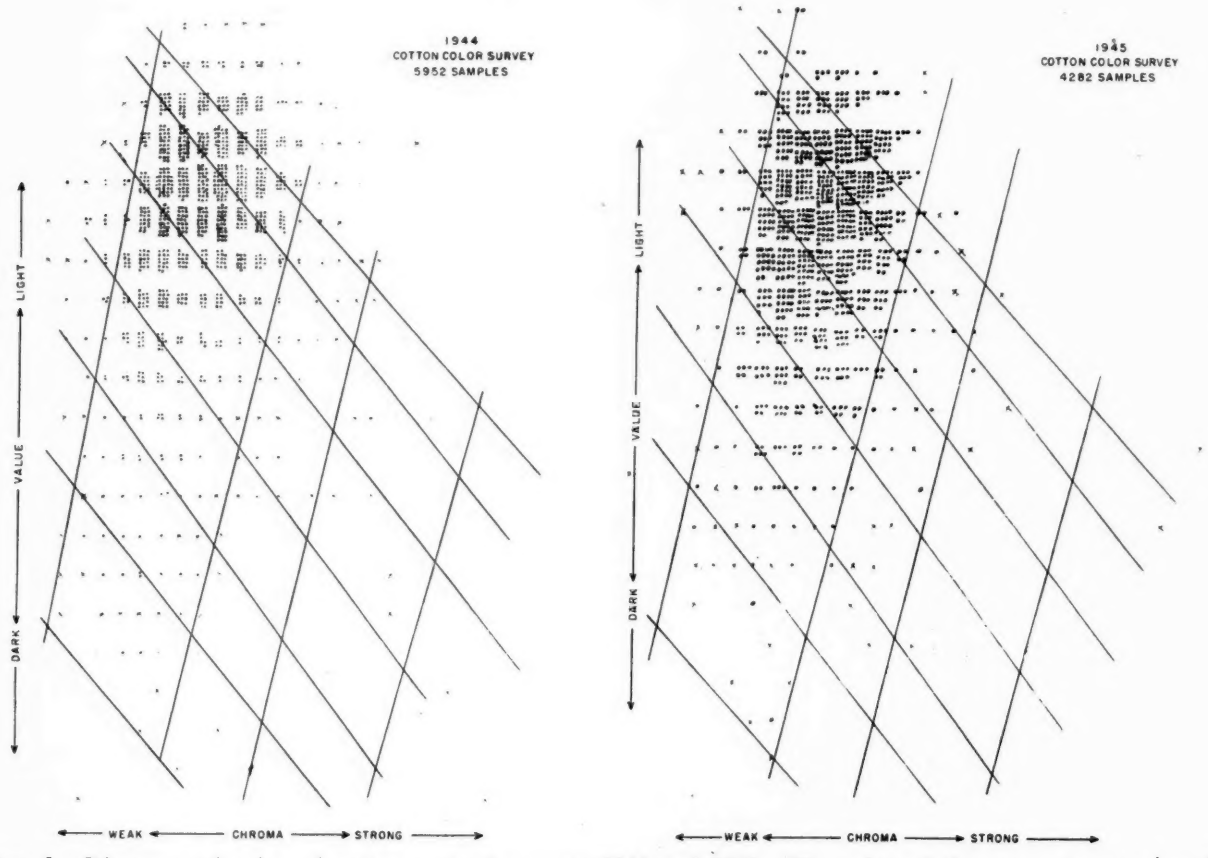


FIG. 6. *Diagrams of color of cotton crops for years 1944 and 1945. The color of these recent crops is not significantly different from the color of crops measured prior to establishment of the 1935 standards.*

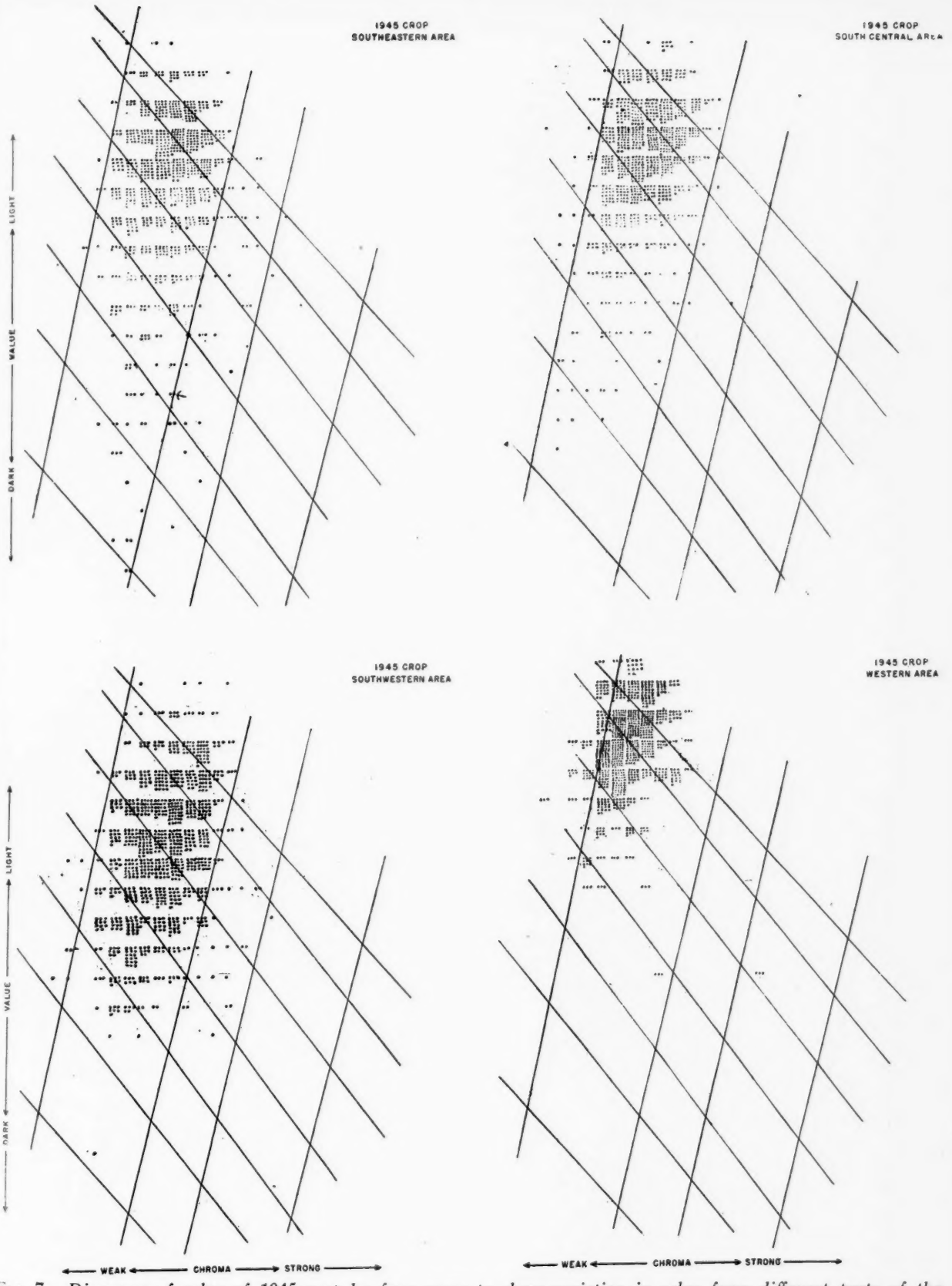


FIG. 7. *Diagrams of color of 1945 crop by four areas to show variation in color from different parts of the Cotton Belt.*

# Cellulose Behavior with Filtered Light from a Carbon Arc Source

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## Introduction

It was noted in 1920 by Pech [1] that if visible light were added to the radiation from a quartz-mercury-vapor lamp the time required to bleach a given sample of cotton fabric was nearly doubled as compared with the time required by the latter source alone. It has also been observed [2] that samples exposed to sunlight under blue glass lost as much and in certain cases slightly more strength than when exposed under clear glass. If it can be proved that the blue component (containing also the near ultraviolet element) in white light when acting alone is materially greater in degradative capacity than when this component is acting in conjunction with all the other normal constituents of white light—as it does in sunlight, for example—such information may be far-reaching in its implications in the field both of accelerated and natural weather-exposure testing. It would suggest that the extent of the degrading action of light depends upon the relative intensities among several wave-length regions in the spectrum. As an illustration of this type of action the effect of ultraviolet radiation upon oxygen might be cited. Ozone is synthesized from oxygen by short ultraviolet and decomposed by longer ultraviolet. The actual yield of ozone therefore depends on the ratio of the intensities of the radiation in these two regions.

In view of the significant variation in the spectral distribution of solar energy, the difficulty experienced in duplication of results in outdoor weather exposure work, and the notable lack of correlation between accelerated weathering tests (using artificial light sources) and actual weather tests, the importance of a careful study of such possible dependence of degrading effect upon wave-length interrelations becomes obvious.

It is the purpose of this paper to present the results of a study of the relative action of various spectral regions or combinations of regions on cotton cellulose with use of a carbon arc lamp as a source of radiation and of Corning glass filters as a means of obtaining certain selected spectral regions of incident energy. This work was preliminary to a more extensive investigation primarily concerned with the variables met with in outdoor weathering tests.

## Historical Data

It has long been recognized that the ultraviolet, or short-wave-length radiations, are in general more active photochemically than the visible and infrared portions of the spectrum. This is especially evidenced by the rapid degradation of cellulose by such artificial sources of ultraviolet as the quartz-mercury arc and the carbon arc lamps, and follows from fundamental laws of photochemistry; absorption of radiant energy will produce chemical change to an extent dependent upon the frequency of the radiation absorbed, higher frequencies (shorter wave lengths) producing greater change because they represent larger amounts of energy per unit of radiation. The energies required to produce most chemical reactions range from about 20,000 to 100,000 calories per mole. It follows, then, that the longer infrared, of wave length greater than 20,000 Å. and less than 14,000 calories per einstein, cannot produce chemical change, whereas the ultraviolet, with energies ranging from 71,000 to several hundred thousand calories per einstein, is, when absorbed, particularly active.

The first recorded work in connection with textile materials dealing with the distribution of destructive power in the spectrum appears to have been carried out in 1883 by Witz [3], who concluded that oxycellulose was formed by the action of blue rays, while red and yellow rays had no action. A. Scheurer in 1910 [4] claimed that light of wave length 3,000 to

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1,860 Å. was responsible for oxidation of cellulose; he also noted that the yellowing of cotton subjected to the radiation from a quartz-mercury lamp was greatly retarded by protecting the sample with a glass screen. Barr [5] in 1915 noticed that the deterioration of doped airplane fabric was much less under red glass than under clear glass. Aston [6] in 1917, resolving sunlight by means of a quartz spectrograph and focusing the rays upon linen threads, deduced, from the proportion of threads which, when tested, broke at the point of application of light, that the destructive effect of light was negligible when the wave length exceeded 3,660 Å. Aston believed that his experiments afforded experimental evidence in support of the theory of F. A. Lindemann, who had calculated that the most effective frequency for ionizing oxygen in intimate contact with linen was $\lambda = 3{,}230$ Å. Similarly, the most effective frequency for decomposing ozone on the fibers was $\lambda = 6{,}010$ Å., suggesting the interesting corollary that orange light should arrest deterioration caused by ultraviolet light. Barr [7], in commenting on the work of Aston and others, was the first to observe that, in possible confirmation of Lindemann's hypothesis, orange light actually did appear to have beneficial effect on fabric. Thus, a filter which passes red and orange light, as well as the blue component, allows slightly less deterioration, as shown by breaking strengths, than a filter which passes the blue alone. Barr also noted another instance of radiation antagonism: that extreme ultraviolet from the quartz-mercury lamp apparently prevents the bleaching which occurs with rays in the near ultraviolet. A third important observation by this investigator was that the location of any apparent maximum effect in the sun's spectrum was most probably that point at which increase in chemical activity was just balanced by the decrease in absolute intensity in this portion of the solar spectrum. This point is probably below $\lambda = 3{,}150$ Å.

As mentioned previously, Pech had found that by augmenting the radiation from a quartz-mercury lamp by visible or infrared rays the time required to whiten unbleached cotton was considerably increased. Appel and Smith [8] in an investigation of the fading of dyed textiles in the light transmitted by various glasses noted that certain dyeings faded less without glass than under glass and pointed out that this suggested a counteracting photochemical action by one part of the spectrum over another. This type of phenomenon is further illustrated in a paper by S. E. Sheppard on the antagonism of radiations in photochemical and photographic reactions [9]. Sheppard states that the idea of antagonistic action of radiation of different frequencies was first specifically formulated by Ritter in 1802.

## Apparatus

For all practical purposes it is impossible to obtain for large surfaces uniform monochromatic illumination of good intensity in various regions throughout the spectrum. In general, glass color filters do not offer a completely satisfactory means of isolating a narrow wave band; single filters do not have sharp cutoffs at both upper and lower limits of a spectral region; and combined filters have such poor transmission values that their use is impractical. The percent transmission in the selected wave band should be higher than 50 percent if inordinately long ex-

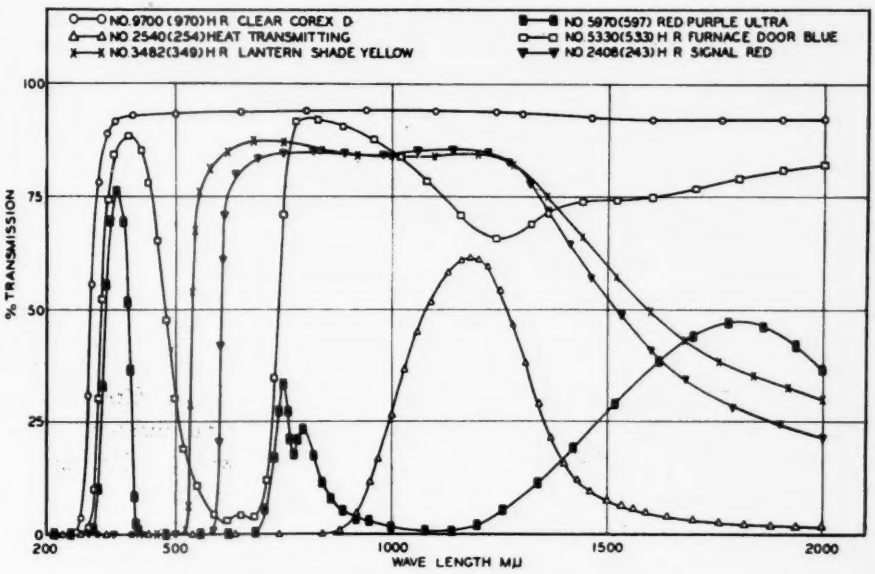


FIG. 1. *Spectral transmission of Corning glass filters. The data were obtained with a Beckman spectrophotometer.*

posures are to be avoided. Furthermore, the transmission curves of all but a very few glass filters have more than one maximum in the spectrum. As a workable compromise for the present purpose, therefore, radiation from the carbon arc was restricted to groups of wave lengths or wave bands in various parts of the spectrum by the use of six Corning glass color filters: Corex D 9700; Red Purple Ultra 5970; Blue 5330; Yellow 3482; Red 2408; and Heat Transmitting 2540. (The filter numbers referred to are Corning Glass Works code numbers.) The transmission curves for these filters are shown in Figure 1.

A 50-volt, 60-ampere, A.C. arc burning National "Sunshine Carbons" was used. This gave a continuous spectrum rich in ultraviolet radiation (Figure 2). The samples of cotton fabric, a kier-boiled 48 x 44 sheeting of 5.6 ounces per square yard, were mounted behind 6½ x 6½-inch squares of filter glass, sometimes in contact with the filter and sometimes with an air space between filter and fabric as the experiment required. The samples were backed and enclosed as protection against reflection from the walls of the test chamber. (Samples shielded from direct light, if not backed with opaque material, show considerable deterioration due to reflected light.) The machine used was the National Accelerated Weathering Unit XIA without the Corex D screens and without the spray. Chromel-alumel thermocouples of fine wire laid against the surface or inserted into the yarns of the fabric sample were used with a Micromax recorder of 0° to 150°C range.

In addition to the carbon arc, tungsten-filament "infrared" lamps, with and without certain of the glass filters, were used for some exposures to supplement data obtained by use of the 2540-infrared filter with the carbon arc. (The distance between sample and light source was 18 inches for both carbon arc and infrared lamp exposures.) To obtain temperature control during exposure to infrared lamps the fabric samples were held in contact with the polished surface of a chromium-plated copper water cell through which water was circulated from a thermostatically controlled bath.

Determination of the distribution of the arc's radiation among the various spectral regions selectively transmitted by the filters was made with a surface thermopile, an 80-junction manganin-constantan pile of the type designed by W. J. H. Moll [10], generating an e.m.f. of about 30 millivolts, as

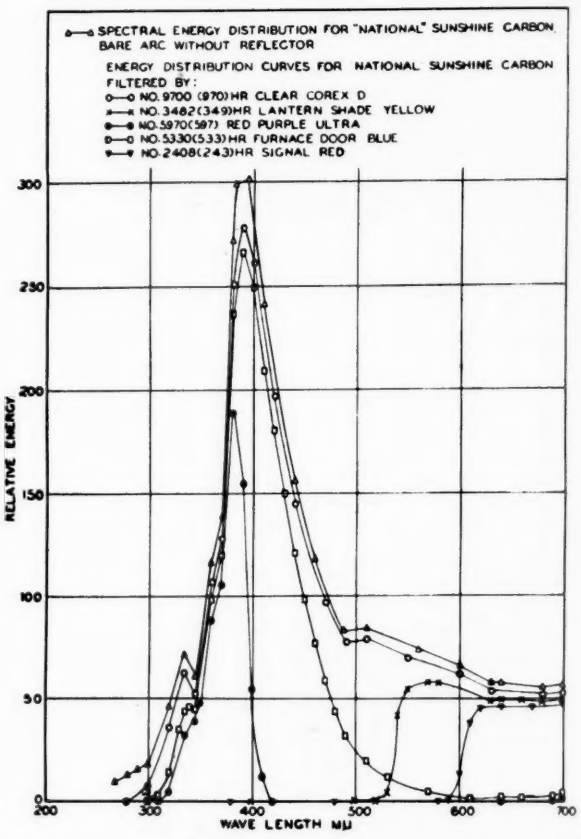


FIG. 2. *Energy distribution in the radiation reaching the samples exposed under the filter glasses.*

measured with a potentiometer, when exposed to the bare carbon arc at a distance of 60 cm. The thermopile was used with a Brown Electronic recording potentiometer of 0- to 35-millivolt range.

## Methods

The first exposures were made on the basis of supplying to each sample through its respective filter an accumulated quantity of radiant energy equal to that received by each of the other samples in what was termed "equal energy" exposures. This was done by extending the exposure time in each case by a factor based on the ratio of the energy passed by each filter to that passed by Corex D. Because of the difference in transmission characteristics of the various filters, the exposure times necessary to make total incident radiation equal in each case varied widely. For instance, the Red Purple Ultra 5970 increased, by an approximate factor of 9 over Corex D, the time required for a given quantity of radiant energy to fall on the sample.

The method used was to start all exposures simultaneously and remove each sample as its calculated exposure time elapsed. Arbitrarily set at 100 hours, the Corex D exposure was found to be sufficiently long to allow the sample which was least affected to show a moderate change in tensile strength and a relatively large change in cuprammonium fluidity. For equal energy, an exposure of 877 hours would thus have been required for the sample screened by the Red Purple Ultra 5970; expediency, however, necessitated using a half-time exposure for this sample.

Since the sample least affected was that which had been exposed behind the Red 2408 filter for a computed time of 158 hours, a number of different sets of samples were run for approximately 158 hours for each set of filters. When the samples were exposed for equal time, the variation of destructiveness with the filters used progressed in substantially the same order as when the samples were exposed for equal cumulative energy. In continued studies, all exposures through the various filters were made for equal lengths of time.

Continuous recording of sample temperatures during exposure in the weathering machine revealed values much higher than those attained by samples during exposure to solar radiations. The results of exposures of samples for varying lengths of time to radiation from tungsten-filament infrared lamps (with and without the use of several of the glass filters), without the complicating factor of the heat generated in the weathering machine, indicated a measurable temperature coefficient of the degrading action of radiation, the existence of which renders significant the temperature of the sample during irradiation. It was found that temperatures of the samples in the weathering machine could be kept more uniform by increasing from ½ r.p.h. to ½ r.p.m. the speed of rotation around the arc of the sample rack. To reduce the temperatures, the vertical sides of the sample rack of the weathering machine were covered with a close mesh net of heavy cotton yarns which was kept saturated with water. Evaporation from this "wick" lowered the temperatures about 25° to an average of 75° to 80°C. The relative humidity of the ambient air within the machine thus modified, measured by means of a wet and dry bulb hygrometer, approximated 50 percent. A series of exposures ranging from 20 to 80 hours, using all of the filters, was made under these conditions of reduced, more uniform temperature and higher relative humidity.

TABLE I. COMPARATIVE DEGRADATION PRODUCED BY EXPOSURE UNDER VARIOUS FILTERS TO EQUAL AMOUNTS OF RADIANT ENERGY *

| | Hours exposed | Loss of breaking strength † (%) | Cuprammonium fluidity † (rhes) |
|---|---|---|---|
| Unexposed control | 0 | — | 2.55 |
| Corex D 9700 | 100 | 48.3 | 22.6 |
| Red Purple Ultra 5970 | 438‡ | 77.2 | 37.2 |
| Blue 5330 | 160 | 62.8 | 28.1 |
| Yellow 3482 | 152 | 22.7 | 9.8 |
| Red 2408 | 158 | 20.0 | 9.2 |
| Heat Transmitting 2540 | 235 | 26.4 | 10.5 |

* Rack speed ½ r.p.h.; temperature about 100° C; estimated sample moisture content less than 0.3 percent.

† Represents an average of 2 exposure sets for 2540 and 5970; an average of 3 exposure sets for the remainder.

‡ This is one-half of calculated exposure time.

Both cuprammonium fluidity measurements (determined by use of the velocity gradient techniques of Conrad [11]) and breaking-strength determinations were used to reveal the extent of cellulose deterioration. In connection with the interpretation of these data it may be stated that, according to Dorée [12], fluidity measurement is by far the most sensitive diagnostic of chemical change in cellulose; chemical breakdown always accompanies but frequently precedes mechanical strength loss brought about by chemical agencies; any increase in fluidity of the cellulose is a potential reduction in the cotton fiber strength.

For measurements of bleaching and yellowing effect due to light, reflectance was measured by means of a Hunter Reflectometer [13] by the method outlined in National Bureau of Standards Circular C429, page 42 [14]. This method determines whiteness or yellowness in terms of apparent reflectance relative to magnesium oxide, using three standardized filters conforming approximately to those required by the I.C.I. (International Committee on Illumination) trilinear coordinate system.

## Comparative Degradation by Different Wave Bands

The data in Table I prove conclusively that, since all of the specimens exposed to equal amounts of radiant energy of different spectral composition are not affected to approximately the same extent, the degree of photochemical activity in cotton cellulose is

TABLE II. COMPARATIVE DEGRADATION PRODUCED BY EXPOSURE UNDER VARIOUS FILTERS FOR EQUAL TIME (158 HOURS) *

| | Strength loss † (%) | Cuprammonium fluidity † (rhes) |
|---|---|---|
| Unexposed control | — | 2.55 |
| Corex D 9700 | 60 | 26.1 |
| Red Purple Ultra 5970 | 61 | 27.5 |
| Blue 5330 | 63 | 28.1 |
| Yellow 3482 | 23 | 9.8 |
| Red 2408 | 20 | 9.2 |
| Heat Transmitting 2540 | 26 | 9.6 |

* Conditions: Rack speed ½ r.p.h.; temperature about 100° C; estimated sample moisture content 0.3 percent.

† Data for all filters are an average of 3 exposures, except 5970, which is an average of 2 exposures.

NOTE: Values for the blue, yellow, and red filter exposures were taken from Table I, the exposure times being considered sufficiently close to 158 hours for comparative purposes.

not a simple linear function of the quantity of radiant energy irrespective of wave length received at the surface of the samples, but rather that the extent of action varies with the character of the incident energy. Bearing in mind that radiant energy can have no effect on a substance unless absorbed by it, the action noted is somewhat curious when the fact is considered that cellulose (in the form of transparent film) has been found to show only a very gradual increase in absorption in proceeding from the infrared through the visible into the ultraviolet. With this exception the result obtained had been expected from photochemical considerations. However, the corroboration obtained was deemed necessary for several reasons: first, no previous work reported had adequately compared results of exposures using colored glass filters on the basis of total energy received, although it was admitted in several instances that the differences in amount of degradation behind such filters were to an unknown extent dependent upon the total transmission of the glasses (that is, a red filter might be expected to protect cotton fabric to a greater extent than clear glass if for no other reason than that it allowed less total energy to impinge upon the sample); second, no reports had been found of investigations into the extent to which degradation of cellulose by irradiation is affected by antagonistic action between long- and short-wave energy; and, third, the possibility that, in solar radiation, the longer-wave-length visible and infrared energies are in such preponderance as to mask the greater unit effect of the shorter-wave-length ultraviolet energy.

TABLE III. DEGRADATION PRODUCED BY OVEN HEAT

| | Temperature (°C) | Time (hrs.) | Loss in breaking strength (%) | Cuprammonium fluidities (rhes) |
|---|---|---|---|---|
| A | 54 | 100 | 3 | 3.0 |
| | | 300 | 2 | 3.1 |
| | | 500 | 7 | 3.5 |
| | 90 | 100 | 13 | 3.7 |
| | | 116 | 3 | 4.0 |
| | | 158 | 11 | 4.7 |
| | | 283 | 14 | 6.3 |
| | | 438 | 14 | 7.3 |
| | | 500 | 17 | 8.3 |
| | Control | 0 | 0 | 2.6 |
| B | 54 | 100 | 3 | 3.0 |
| | 70 | 100 | 0 | 3.2 |
| | 80 | 100 | 0 | 3.6 |
| | 85 | 100 | 1 | 3.9 |
| | 95 | 100 | 5 | 4.3 |
| | 105 | 100 | 0 | 5.1 |
| | 110 | 100 | 11 | 5.9 |
| | 115 | 100 | 17 | 8.8 |
| | 120 | 100 | 20 | 10.0 |
| | 180 | 16 | 69 | — |

If the filters fulfilled the ideal condition—that is, of having uniform transmission between sharply defined limits—the "equal energy" procedure would give a means of comparing a given amount of energy from one narrow portion of the spectrum with the same amount from another portion. Actually, many of the filters transmit in regions other than that of their dominant color, so that extending the exposure by a factor based on total transmission multiplies the unwanted energy as well as the desired wave band, and thus does not result in a comparison of equal amounts of spectrally pure radiation from various parts of the spectrum. Nevertheless, since the quality of radiation passed by each filter is different from that passed by any other filter, the test is still valid as a means of determining the difference, where it exists, in the photochemical activity from one portion of the spectrum to another.

In analyzing the data in Table II, it should be borne in mind that conditions other than the effect of the various filters contributed to some extent to the amount of degradation recorded: that is, the relatively high temperatures of the samples, resulting from radiation from the burning carbons upon the glass surface, and the comparative dryness of the samples. (Temperatures ranged from 90°–110°C, and the equilibrium moisture content of the samples in the heated air of the exposure chamber did not exceed about 0.3 percent when the air outside had a

TABLE IV. DEGRADATION BY FILTERED ARC RADIATION VS. TIME *

| Time (hrs.) | | Corex (Clear) | 5970 (Ultraviolet) | 5330 (Blue) | 3482 (Yellow) | 2408 (Red) | 2540 (Infrared) | Unfiltered |
|---|---|---|---|---|---|---|---|---|
| 20 | % BSL † | 10 | 4 | 11 | 2 | 1 | 2 | 60 |
| | Fluidity | 5.5 | 5.5 | 4.8 | 2.03 | 2.23 | 1.99 | 17.4 |
| 40 | % BSL | 13 | 17 | 10 | 5 | 3 | 1 | 68 |
| | Fluidity | 7.45 | 7.01 | 6.59 | 2.32 | 2.57 | 2.32 | 21.0 |
| 60 | % BSL | 20 | 21 | 20 | 0 | 0 | 0 | 76 |
| | Fluidity | 8.82 | 10.08 | 10.20 | 2.53 | 2.40 | 2.62 | 23.7 |
| 80 | % BSL | 28 | 24 | 25 | 0 | 0 | 0 | 80 |
| | Fluidity | 13.06 | 12.60 | 13.85 | 3.21 | 3.20 | 3.03 | 26.0 |

* Conditions: Rack speed 1.3 r.p.m.; average temperature about 80° C; estimated sample moisture content not less than 3.5 percent.

† BSL = Breaking strength loss.

NOTE: Fluidity of unexposed control was 1.24. The fluidity values recorded in this table have not been adjusted for velocity gradient.

relative humidity of about 50 percent.) Data presented in Table III show, however, that heat alone can account for only a small fraction of the total degradation values noted in Table II. Thus spectral distribution of the radiant energy incident upon the samples is indicated as the primary cause of the degradation. When conditions in the weathering apparatus are changed so that sample temperature and moisture relations approach more nearly those encountered in actual weathering, the extent of the degradation is markedly reduced (Table IV); the relative effect of the different portions of the spectrum, however, which is the chief concern here, remains substantially the same.

Further examination of Table II shows that with the exception of the Corex D exposure, the degrading effect evidently increased with extension of the incident radiant energy toward the short wave-length end of the spectrum. It must be remembered that the quantity of energy from the arc, both over the entire spectrum and in limited bands transmitted by the several filters, varies considerably, and the extents of degradation should be compared with this in mind. Thus the energy acting upon the sample under the ultraviolet-transmitting glass was only about one-tenth that acting upon the sample under Corex. Yet the degradation was the same. It would therefore appear at first that the energy of wave length greater than about 4,200 Å. (the approximate upper limit passed by the ultraviolet-transmitting glass) is of no consequence with regard to cellulose degradation in comparison with that of shorter wave length. The question immediately arises, however, as to why the sample under Corex D, which received much more radiation not only over the entire spectral range but also in the area generally admitted to be responsible for degrading activity, was not more degraded than the sample under ultraviolet-transmitting glass. The latter received only 11.4 percent of the total energy (and 20 percent of the energy between 3,000 and 5,000 Å.) passed by the Corex D. A further example is the blue (5330) glass, which passes only 65 percent of the total energy (and 70 percent of the energy between 3,000 and 5,000 Å.) passed by the Corex D; yet samples under this glass, too, were degraded to a slightly greater extent than those exposed under Corex D. From these results as well as from those previously published of work along similar lines, there appears to be no doubt that there is a region of the spectrum which acts in opposition to the region (say 3,000 Å. to 4–5,000 Å.) acknowledged to be largely responsible for the photochemical deterioration of cotton cellulose. It would seem from analysis of the source emission-filter transmission resultant incident energy curves (Figure 2) that this "opposing" spectral region is principally in the yellow-orange-red portion of the spectrum since the transmission of this region constitutes the principal difference between the Corex D and the blue or the ultraviolet-transmitting glasses.

If this "antagonistic effect" can be shown to exist to an important degree under actual outdoor weathering conditions, the implication is that the intensity ratio existing between certain spectral regions in solar radiation might be of equal or greater impor-

TABLE V. EFFECT OF IRRADIATION BY TUNGSTEN FILAMENT INFRARED LAMP

| Filter | Temperature (°C) | Time (hrs.) | Cuprammonium fluidity (rhes) |
|---|---|---|---|
| Bare Lamp | 35 | 400 | 3.29 |
| Bare Lamp | 40 | 144 | 3.14 |
| Bare Lamp | 60 | 30 | 3.02 |
| Bare Lamp | 90 | 65 | 4.58 |
| 5330 | 35 | 400 | 6.91 |
| 5330 | 85 | 65 | 5.48 |
| 3483 | 90 | 65 | 4.05 |
| 2408 | 90 | 65 | 3.91 |
| 2540 | 35 | 400 | 2.96 |
| 2540 | 90 | 40 | 3.36 |

tance than such recognized variables as total intensity, temperature, and moisture relations in exposure test conditions. This would render necessary a knowledge of the radiation in several wave-length bands incident upon weather-exposed samples and the changes in their relationship with time. Accurate knowledge and close control of this factor in artificial weathering tests may be required. To speculate further, a given total amount of radiant energy from the sun might be expected for this reason to produce considerably less deterioration than the same total amount of energy from a carbon arc source because the ratio short-wave/long-wave radiation is in general much less in the case of energy from the sun.

Although the strength loss and fluidity rise of the samples exposed behind the yellow, red, and heat-transmitting filters does not approach that of either the blue, the ultraviolet, or clear glass filters, the amount of degradation is nevertheless significant. Is the degradation a photochemical effect, a heat effect, or both? The effect of heat alone (Table III) evidently cannot account for the extent of the action noted; similarly, radiant energy of $\lambda$ greater than 5,000 Å. in the absence of such excessive heat, and in the presence of normal amounts of moisture, apparently is without marked effect, as demonstrated in Table IV. Therefore the conclusion may be reached that the action under these three filters (yellow, red, and heat-transmitting) is due either to a concurrent heat-light effect or to light acting upon substantially moisture-free cellulose.

Although the data obtained in the investigation of the heat-light relationship by exposure to infrared radiation, under temperature-controlled conditions, are insufficient for more than an indication of the trend (Table V), it appears that no very significant degradation of cellulose can be expected from infrared radiation at normal temperatures even when the total incident radiant energy exceeds many times that received in the 158-hour carbon arc experiment. When elevated temperatures are employed, however, deterioration begins to be measurable, and again is greater than can be ascribed to heat alone, tending to substantiate the observation that there is a concurrent heat-light effect greater than either effect alone. It is further noteworthy that when the radiation from the tungsten source was modified by interposing a blue glass (5330) filter, degradation became significant at normal (35°C) temperature; this can be interpreted only as another example of radiation antagonism in which removal of the yellow-orange-red components (amounting to perhaps 5 percent of the total energy from the lamp) resulted in an increase in degrading activity of the radiation. An exposure for the same length of time under the heat-transmitting filter, which, like the blue filter, removes the yellow-orange-red rays (in addition to removing the blue rays), showed no appreciable difference in effect from the unfiltered exposure, a fact which would suggest that the relatively small blue component from this source may play a large part in deterioration if unopposed by the yellow-orange-red region.

### Bleaching and Yellowing Effect of Radiant Energy

Another feature of the radiant energy effect on cellulose is the bleaching and yellowing of clean cotton fabric under various conditions of exposure. While it has not been found to relate to degradation in any specific way it is, nevertheless, a very interesting phenomenon. In the present work it was of interest to learn something of the spectral distribution of radiation that bleaches or yellows cellulose in order to determine whether any correlation exists between this effect and degradation.

Investigation of bleaching and yellowing by radiant energy is somewhat complicated by the fact that the temperature of the exposed materials is apparently critical with respect to the net effect. Thus Launer and Wilson [15] have shown that paper samples exposed for 10–15 hours to a Pyrex-enclosed carbon arc lamp filtered to exclude radiation below 3,300 Å. would be either bleached or yellowed depending upon whether the temperature was controlled (near 30°C)

TABLE VI. BLEACHING AND YELLOWING EFFECT OF RADIANT ENERGY *

| Filter | Whiteness | | | Yellowness | | |
|---|---|---|---|---|---|---|
| **A. Carbon Arc Exposures** | | | | | | |
| Control, unexposed | 0.6801 | | | 0.1088 | | |
| | Dry | Moist | Wet | Dry | Moist | Wet |
| No filter | 0.2830 † | 0.4120 ‡ | 0.8719 | 0.2532 † | 0.2070 ‡ | 0.0339 |
| Corex D | .7210 | .7891 | — | .0936 | .0691 | — |
| 5970 | .6799 | .7075 | — | .1113 | .1000 | — |
| 5330 | .7110 | .7598 | — | .0989 | .0793 | — |
| 3482 | .6368 | .6769 | — | .1253 | .1098 | — |
| 2408 | .6545 | .6561 | — | .1186 | .1174 | — |
| 2540 | .5681 | .6174 | — | .1496 | .1319 | — |
| **B. Infrared Lamp Exposures ** ** | | | | | | |
| | Whiteness | | | Yellowness | | |
| No filter | 0.7194 | | | 0.0933 | | |
| 2540 | .6833 | | | .1064 | | |

* Higher values indicate greater whiteness or yellowness; 100-hour exposures except where indicated.
† 20-hour exposures.
‡ 40-hour exposures.
** 400-hour exposures.

or not controlled (allowed to rise to 160°C or above). It has been reported [16] that sunlight caused much more bleaching of paper samples exposed in England than in the warmer climate of Cairo, Egypt; and, moreover, that in Cairo the portions of the samples covered with opaque paper (and heated to about the same extent as the uncovered portions) yellowed more than the exposed portions. From these observations the dependence of bleaching action upon temperature is clear.

Table VI shows the bleaching or yellowing obtained by exposure to the carbon arc, unfiltered and filtered, under several conditions of temperature and moisture content, and by exposure to the tungsten infrared lamp. With the temperature uncontrolled in any way (sample at about 100°–105°C), the unfiltered radiation from the carbon arc produced excessive browning. When the temperature was lowered (to about 70°) with the simultaneous introduction of water vapor, the sample continued to be strongly yellow; if, however, the sample was kept continuously wet with distilled water during the exposure, resulting in a sample temperature of about 40°C, marked bleaching occurred. This is somewhat surprising because the results obtained under a quartz-mercury lamp, where the sample temperature was quite low, indicated that, apart from temperature effect, the ultraviolet radiation shorter than 3,000 Å. was a cause of yellowing; water present as liquid or vapor would not be expected to filter out the yellowing ultraviolet. Moreover, very severe degradation in this instance pointed to a high incidence of the shorter ultraviolet.

With temperature uncontrolled, the color reaction of the samples under the filters suggested that radiation up to about $\lambda = 5{,}000$ Å. has a bleaching effect. Although samples exposed to radiation of longer wave length are in most cases definitely yellowed, it cannot be concluded that this action is any more than a lack of a bleaching effect to oppose the yellowing effect of heat. Under all conditions employed there is a rather sharp demarcation in going from the heat-transmitting, the red, and the yellow filter exposures, under which the sample tends to yellow, to the ultraviolet, blue, and the Corex filter exposures, under which the sample always bleaches; this cannot be explained on the basis of quantity or radiant energy received since the ultraviolet-transmitting glass passes less than half as much as the yellow glass yet bleaches much more. No evidence of any antagonistic action between wave-length bands, relative to bleaching effect, within the limits of the solar spectrum, has been found; it is evident, however, that at least under certain conditions the ultraviolet of wave lengths less than 3,000 Å. tends to yellow whereas the longer ultraviolet tends to bleach.

If near and middle infrared radiation of itself possessed the property (suggested by its relation to heat) of bringing about yellowing of cellulose, the 400-hour exposures to the tungsten infrared lamp, unfiltered, or with visible radiation excluded by use of the heat-transmitting filter, should produce some

evidence of this tendency. From the data given in Table VI, this does not appear to be the case.

Under special conditions light increases the whiteness (bleaches) and depolymerizes the cellulose at a rate roughly proportional to the logarithm of the time of exposure. If the temperature or other conditions are changed, progressive degradation may be accompanied by increased yellowing rather than bleaching. A 10-hour exposure of a sample, one-half of which was kept wet while the other half remained dry, to unfiltered carbon arc radiation resulted in almost identical degradation of each half as measured by fluidities (13.5 rhes for each), but the dry portion was markedly yellowed while the wet portion was markedly bleached. Thus bleaching or yellowing bears no constant relation to cellulosic degradation.

## Summary

Evidence has been presented which tends to substantiate the theory, previously expressed, that certain wave length regions in the spectrum may interact in such a manner as to reduce the net degrading effect on cotton cellulose of the total incident radiant energy. Thus clear glass has a slightly greater protective effect when used to screen a sample of cotton fabric from carbon arc radiation than does blue glass even though the latter has a lower transmission throughout the spectrum.

The bleaching and yellowing action of radiant energy of various spectral distributions under several conditions has been noted. No direct relation between this effect and degradation is apparent.

The protective effect of red and yellow glasses on cellulose exposed to light is shown to be due to the selective rather than total transmission properties of these filters.

## Acknowledgment

The cooperation of M. E. Jefferson in this study is gratefully acknowledged; and thanks are extended to his coworkers for the measurement of transmission characteristics of the various glass filters used.

Appreciation is also expressed to members of the Colloidal Properties Section of the Cotton Fiber Research Division for the fluidity data here reported, and to J. E. Sands and Miss J. D. Hall for carrying out a number of the physical tests entailed.

The spectral distribution curve for the "Sunshine" carbon, bare arc without reflector, was reproduced from Catalog Section A–4300, Radiation Characteristics of National Industrial and Therapeutic Carbons, and printed with the permission of the National Carbon Company, Incorporated.

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# ABSTRACTS

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## ANALYSIS: TESTING: LABORATORY METHODS

★

### Abrasion Testing

**Abrasion and wear of testing of textile fabrics.** T. R. Dawson. *J. Rubber Research* **15**, 65–91 (1946) (through *Chem. Abstr.* **40**, 3609[4] (June 20, 1946)).

A review and discussion, with 155 references.

*Text. Research J. Sept. 1946*

**Textile testing in Germany.** Anon. *Text. Mercury and Argus* **114**, 736, 737, 739 (May 17, 1946).

High lights from a report of the British Intelligence Objectives Sub-Committee describing abrasion testers used by the Germans during the war. 3 types of fabric testers and 5 types of testers for yarns or filaments are described.

H. J. Burnham

*Text. Research J. Sept. 1946*

### Color Measurement

**The measurement of color.** W. D. Wright. *Rayon Text. Mo.* **27**, 145–8 (Mar. 1946).

A brief review. 5 references.

*Text. Research J. Sept. 1946* A. R. Martin

### Impact Testing

**Impact determinations based on the arrested fall of a body.** L. F. Dytrt and W. Specht. *J. Franklin Inst.* **239**, 115–25 (Feb. 1945).

The testing arrangement involves a setup which permits the object under test to be dropped from a predetermined height onto an elastic, restraint-producing unit—a spring—which is mounted on a rigid base. The height from which an object must be dropped to produce a given amount or type of damage (usually determined by visual inspection) may in itself serve as a measure of its capacity to withstand impact, or this height may be used, together with the constants of the apparatus, to calculate the actual impact. The theory of such calculations is developed, and one example is given. The method has been applied largely to composite manufactured articles such as electrical equipment. W. E. Davis

*Text. Research J. Sept. 1946*

### Molecular Weights Determined by Light Scattering

**A photoelectric instrument for light-scattering measurements and a differential refractometer.** P. P. Debye. *J. Applied Phys.* **17**, 392–8 (May 1946).

A photoelectric goniophotometer for measuring the angular intensity distribution of scattered light from a high-polymer solution is described. A description of a differential refractometer is also given. With these instruments, measurements on solutions of a high polymer may be obtained from which weight-average molecular weight may be calculated. Data on polystyrene and on certain polyvinyl ethers are presented. The effect of cold milling on the molecular weight of polyvinyl isobutyl ether is discussed. The intrinsic viscosity of the polymer decreases with milling, but the weight-average molecular weight as determined by light-scattering measurements remains substantially constant.

*Text. Research J. Sept. 1946* T. J. Dietz

### Review of Vinyl Plastics

**Advances in the field of plastics.** I.P. Losev and E. B. Trostyanskaya. *Uspekhi Khim.* **14**, 395–412 (1945) (through *Chem. Abstr.* **40**, 3299[5] (June 10, 1946)).

Methods are reviewed for measuring molecular weight and degree of polymerization of plastics. Methods of preparation, properties, and uses are described for polymers of ethylene, isobutylene, vinylidene chloride, polyvinyl alcohols, vinyl ethers, polyvinyl carbazoles, polyvinyl naphthalene, and polyvinyl ketones. The nature of copolymerization is discussed. 54 references.

*Text. Research J. Sept. 1946*

### Electrostatic Properties of Rubber

**Electrostatic and tensile properties of rubber and GR-S at elevated**

**temperatures.** R. S. Havenhill, H. C. O'Brien, and J. J. Rankin. *J. Applied Phys.* **17**, 338–46 (May 1946).

An apparatus for measuring electrostatic contact potentials of rubberlike materials at elevated temperatures is described. An electrostatic charge is acquired by a steel ball in rolling on a sheet of the test material which is mounted in an inclined position. The rolling ball leaves the test specimen and drops into a metal cup connected to a suitable charge-measuring device. The temperature of the specimen is adjusted by means of an electric hot plate. The electrostatic contact potential is shown to increase with an increase in test temperature. GR-S vulcanizates exhibit a greater increase than natural rubber vulcanizates under similar conditions. Contact potential appears to be inversely related to tensile strength. Certain compounding ingredients such as egg albumin, finely divided $SiO_2$, and $Na_2SiO_3$ are shown to reduce the negative charge of GR-S latex specimens. T. J. Dietz

*Text. Research J. Sept. 1946*

## Tire Cord Fatigue

**Fatigue failure of rayon tire cord.** R. C. Waller and W. E. Roseveare. *J. Applied Phys.* **17**, 482–91 (June 1946).

Tire-cord fatigue tests are characterized and interpreted in terms of the following parameters: magnitude and frequency of the cyclic stroke, average load, minimum load, temperature, and humidity. By varying one test parameter at a time, it is shown that the effects of creep and degradation are minimized by using a high frequency and a high stroke. The relative rating of two samples of rayon depends on the parameters of the test and on the modulus and twist structure of the samples. Fatigue breakdown is interpreted in terms of progressive fracture under localized strains occurring at the peak stress of the cycle. A comparison of the fatigue behavior of rubbers, metals, and tire cord suggests they may all involve the same basic process of crack growth. Authors

*Text. Research J. Sept. 1946*

## Water-Vapor-Permeability Tester

**Water-vapor-permeability tester.** F. T. Carson and Vernon Worthington. *Paper Ind. Paper World* **27**, 1799–805, 1816 (1946) (through *Chem. Abstr.* **40**, 3942[6] (July 20, 1946)).

A conditioning and testing cabinet is described in which the hygrometric conditions are maintained by equilibrium with a saturated solution of an appropriate salt. The temperature of this solution and of the testing chamber is held constant by means of an envelope of moving air that completely surrounds the testing chamber, an open-coil heater, and a thermoregulator used to control the temperature of this air bath. Devices for supporting and weighing the permeability cells in the cabinet, without disturbing the hygrometric conditions, are explained in detail. The cells, hung by hooks from a rotary suspension disc, can be suspended one at a time from a weighing rod attached to a balance. Interlocking mechanisms for selecting and picking up the cells facilitate the weighing and protect the apparatus and the permeability cells from accidental injury. A method and apparatus for mounting the specimens in the permeability cells are described also. Materials covering a large permeability range can be accommodated. Some suggestions are made for accelerating the testing of good moisture barriers.

*Text. Research J. Sept. 1946*

## Yarn Diameter

**Coil tester accurately gages yarn diameters.** A. E. McKenna. *Textile World* **96**, 120, 121, 190 (June 1946).

Description of a machine in which yarn is wound in coils side by side on a rod and the number of coils per inch or more used to determine actual yarn diameter. Results from the machine agree closely with Ashenhurst's formula for cotton yarns from 12s to 60s. This formula is: diam. $= \frac{1}{0.92\sqrt{840\,N}}$, where $N$ is actual yarn number.

H. J. Burnham

*Text. Research J. Sept. 1946*

# CHEMICAL AND PHYSICAL RESEARCH

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## Criticism of Brönsted's Theory of Acids

**Definition of acids and bases.** Guy Emschwiller. *Compt. rend.* **221**, 549–51 (1945) (through *Chem. Abstr.* **40**, 3044[6] (June 10, 1946)).

The classical definition of acids and bases is preferred to that of Brönsted (*C.A.* **17**, 3821). According to E., in reactions between hydrolyzable substances, the primary and more important action is the ionization of the solvent water, followed by the combination of the resulting $H^+$ and $OH^-$ ions with other substances. This point of view is illustrated by such actions as the acidic behavior of $Al(H_2O)_6^{+++}$, and the reactions of gaseous $NH_3$ and of $SO_2$. Further, the Brönsted approach does not simplify the mathematics of such cases, as is frequently assumed.

*Text. Research J. Sept. 1946*

## Cellulose Sorption

**The hydrates of cellulose.** P. H. Hermans and A. Weidinger. *J. Colloid Sci.* **1**, 185–93 (Mar. 1946) (through *Bull. Inst. Paper Chem.* **16**, 385 (May 1946)).

It is shown that the formation of true hydrates plays a part in the process of moisture absorption in cellulose fibers. The existence of two hydrates, called hydrate *I* and hydrate *II*, can be derived from x-ray data. Crystalline hydrate *I* is formed when cellulose *II* (the modification of "mercerized" cellulose) is exposed to water vapor and hence this modification, in contrast to current statements in the literature, exhibits so-called "intramicel-

lar" swelling. Cellulose *I* (native modification) does not show this phenomenon. Crystalline hydrate *II* is identical with the "water cellulose" of Sakurada and Hutino (cf. *B.I.P.C.* **7**, 202–3). It is formed when other cellulose compounds containing water are decomposed at low temperature. The lattice constants of both hydrates are given in a table. If their composition be expressed by $C_6H_{10}O_5 \cdot pH_2O$, the value of $p$ is most probably $\frac{1}{3}$ or $\frac{1}{2}$ in hydrate *I* and $1\frac{1}{3}$ or $1\frac{1}{2}$ in hydrate *II*. The point of view is adopted that the crystalline part of fibers consisting of cellulose *II* takes part in the process of sorption by the formation of hydrate *I*, whereas crystalline cellulose *I* does not. In the amorphous part of the fiber, both hydrates are always formed if sufficient water is absorbed.

*Text. Research J. Sept. 1946*

## Condensation and Polymerization

**Condensation and polymerization.** Pierre Piganiol. *Inds. plastiques* **2**, 36–43 (1946) (through *Chem. Abstr.* **40**, 3297[9] (June 10, 1946)).

A review of general character of macromolecules, the nature and kinetics of polymerization, and polycondensation.

*Text. Research J. Sept. 1946*

## Plasticization of Cellulose Acetate

**The mechanism of plasticization of cellulose acetate by triphenyl phosphate.** Georges Champetier and Pierre Clément. *Compt. rend.* **222**, 92–4 (1946) (through *Chem. Abstr.* **40**, 3298[5] (June 10, 1946)).

The configuration of cellulose acetate lends itself to intramolecular penetration of triphenyl phosphate. There does not appear to be any solvation properly speaking, but a plasticization by molecular insertion with the aid of a previous separation of the cellulose molecules.

*Text. Research J. Sept. 1946*

## Review of Macromolecular Compounds

**Recent investigations of macromolecular compounds.** C. Koningsberger. *Chem. Weekblad* **39**, 386–9 (1942) (through *Chem. Abstr.* **40**, 3032[1] (June 10, 1946)).

A review, with 19 references.

*Text. Research J. Sept. 1946*

## Pectinic Substance

**The effect of chlorine dioxide on pectinic substances.** H. Pallmann and H. Deuel. *Experientia* **1**, 89–90 (1945) (in German) (through *Chem. Abstr.* **40**, 3727[7] (July 10, 1946)).

Preliminary studies indicated that in contradistinction to lignin the higher-mol. pectinic substances are not attacked and broken down by $ClO_2$. Therefore, $ClO_2$ can be successfully used in the study of pectin linkages in plant materials.

*Text. Research J. Sept. 1946*

## Polymerization

**Catalysis and polymerization.** M. Steegmuller. *Plastiques* **1**, 11–15, 47–52 (1943) (through *Chem. Abstr.* **40**, 3644[6] (June 20, 1946)).

Review with 30 references. Unsaturated groups such as —C≡C—, >C=C<, >C=N—, —C≡N, and >C=O make compounds accessible to polymerization. Thermodynamic laws predetermine the pressure and temperature at which polymerization takes place and the maximum yield of the desired end-product but not the time required. Outside factors necessary to speed up the reaction or to guide it in the right direction are heat, light, pressure, and chemical agents (catalysts). Elevated temperatures alone give mostly a mixture of polymers and may be harmful if the initial or end-products are unstable. Catalysts are selected by elimination. Optimum conditions are described for the polymerization of $C_2H_2$, $C_2H_4$, isobutylene, styrene, vinyl esters, butadiene, and homologs, etc. Solvents as a rule slow down the polymerization and give polymers of lower molecular weight.

*Text. Research J. Sept. 1946*

## Polymerization of Olefins

**Polymerization of olefins and diolefins in suspension and emulsion. Part I.** W. P. Hohenstein and H. Mark. *J. Polymer Sci.* **1**, 127–46 (Mar. 1946).

The literature on polymerization in solution, suspension, and emulsion is reviewed with emphasis on suspension or pearl polymerization. New data are presented on the following: (1) initial rates of polymerization of styrene, methyl methacrylate, and vinyl acetate, (2) influence of water-soluble activators like $NaHSO_3$, (3) influence of initial size of monomer droplets on initial rates, and (4) a study of the particle size of monomer and polymer during polymerization. E. D. Klug

*Text. Research J. Sept. 1946*

## Crystallization of Rubber

**Crystallization of unvulcanized rubber at different temperatures.** Lawrence A. Wood and Norman Bekkedahl. *J. Applied Phys.* **17**, 362–75 (May 1946).

Samples of relaxed, unvulcanized, natural rubber are subjected to various temperatures between + 40° and − 60°C and volume changes are observed. Crystallization is measured as a change in volume by means of a mercury-filled dilatometer. The rate of crystallization is greatest at about − 25°C, but specimens crystallize at any temperature between − 50° and + 20°C. The melting of crystallized rubber is shown to occur over a range of temperature, and depends upon the temperature at which crystallization is induced. Recrystallization and the nature of the crystals are also discussed. 78 references.

*Text. Research J. Sept. 1946* T. J. Dietz

## Sound-Absorption Qualities of Fibers

**The absorption of sound in a homogeneous porous medium.** R. A. Scott. *Proc. Phys. Soc.* **58**, 165–83 (Mar. 1946).

The theory of the propagation of sound in isotropic, homogeneous, porous media, such as cotton-waste,

felt, and rock wool, is discussed. Experimental methods for determining attenuation constant, velocity of propagation, and normal acoustic impedance are described. From these data, the effective inertia, compressibility, and porous resistance of the test material may be calculated. At low frequencies, the increase in effective inertia of the air within the specimen is attributable to movement of the fibers. At higher frequencies, fiber movement is small and the effective inertia of the air is reduced. The effective compressibility of the air in the specimen depends principally upon the elasticity of the air itself although heat generated during the compression cycle is absorbed by the fibers. The porous resistance of the absorbing material is shown to be independent of frequency below 200 c.p.s. Above this value, the porous resistance increases with increasing frequency. T. J. Dietz

*Text. Research J. Sept. 1946*

## Oxidized Starch

**Oxidized starch.** Fritz Müller. *Helv. Chim. Acta* **29**, 21–6 (1946) (in German) (through *Chem. Abstr.* **40**, 3406[7] (June 20, 1946)).

Oxidized starch (*I*) made by treating wheat starch first with 5% $KMnO_4$ and then with $NaHSO_3$ and HCl was subsequently treated with various color reagents to determine whether new functional groups, e.g.,—CO or —COOH, were formed similar to those in oxidized cellulose (*II*) (*C.A.* **33**, 3141[5]). Several reagents used on *II*, such as methylene blue, Berlin blue, and Schiff's reagent, were unsuitable for *I* because they also responded to unmodified starch and did not distinguish between carbonyl reactions and ordinary adsorption. In 9 experiments in which *I* and a control were treated with $AuCl_3$ solution (Haller, *C.A.* **26**, 296, 3661; **34**, 7137[1]) 5 experiments showed no change for either sample while in 3 experiments the control reduced the gold to a black colloidal soluble. Prior treatment of the samples with Na dithionate ($Na_2S_2O_4$), followed by washing and treating with $AuCl_3$, gave a deep black *I* and an orange-colored control. Most successful differentiation was obtained with substituted hydrazines followed by coupling with diazotized compounds. Thorough washing between reactions was imperative. *I* treated with a solution of 2-hydrazino-8-naphthol-3,6-disulfonic acid (*III*) and coupled with 4,10-tetrazobenzidine-2,8-disulfonic acid (*IV*) gave a dark brownish-red product whereas a control became light brownish-red. Phenylhydrazine-*p*-sulfonic acid, 1-hydrazino-8-naphthol-3,6-disulfonic acid, and 2-hydrazino-8-naphthol-6-sulfonic acid were interchangeable with *III* and diazotized sulfanilic acid suitably replaced *IV*. Analogous experiments with 1-amino-8-naphthol-3,6-disulfonic acid and a diazotized compound showed adsorption of these substances. These colors were eluted from *I* quite easily but only with difficulty from the control. The starches were not colored sufficiently for dichroic effects to be noted and no differences in double refraction could be found between *I* and the control. Oxidation apparently did not injure the fine structure of the granule.

*Text. Research J. Sept. 1946*

## Structure of Starch

**The structure of starch granules. II.** Robert Haller. *Helv. Chim. Acta* **28**, 450–4 (1945) (in German) (through *Chem. Abstr.* **40**, 4235[8] (July 20, 1946)).

The starch-iodide complex prepared with I water differs macroscopically and microscopically from the starch-iodide complex obtained with $KI_3$. I water may be thought of as an iodine hydrosol which is absorbed on the peripheral cell membrane and does not penetrate into the granule, in an analogous fashion to the staining of cellulose fibers with substantive dyes. In contrast, $KI_3$ in solution is dispersed as individual mols. which penetrate through and stain the starch granule in a manner similar to dyeing with basic dyes, e.g., methylene blue. Thus, the peripheral membrane of native starch grains contains cellulose as a framework.

*Text. Research J. Sept. 1946*

## Styrene Content of GR-S

**Spectrophotometric determination of the styrene content of butadiene-styrene copolymers.** E. J. Meehan. *J. Polymer Sci.* **1**, 175–82 (May 1946).

The ultraviolet absorption of polystyrene, with maximum absorption at 262 mμ, is due to the presence of phenyl residues in the polymer. The specific extinction coefficient is constant, i.e., independent of the molecular weight of the polymer. This shows that the extinction of the phenyl residues is additive. On the basis of this fact it is shown that the styrene content of a butadiene-styrene copolymer (such as GR-S rubber) can be determined by ultraviolet spectrophotometry. The relative precision of the determination is about 1%; the probable relative accuracy is about 3%. Author

*Text. Research J. Sept. 1946*

## Swelling and Hydration

**Anisotropic swelling (preliminary communication).** J. J. Hermans. *Rec. trav. chim.* **65**, 121–4 (Feb. 1946) (in English) (through *Bull. Inst. Paper Chem.* **16**, 480 (June 1946)).

A formula is proposed for the swelling anisotropy of originally isotropic fibers of regenerated viscose cellulose in terms of orientation of the structural elements. The derivation of this formula is discussed.

*Text. Research J. Sept. 1946*

## Swelling Properties of Fibers

**Structure of natural fibers and their swelling properties.** Karl Lauer. *Papier-Fabr. Wochbl. Papierfabr.* **1944**, 268–71 (through *Chem. Abstr.* **40**, 3893[6] (July 10, 1946)).

Without giving the methods used, L. presents data which show that between the degrees of polymerization (D.P.) of 2850 and 580 (obtained by graded hydrolysis), unmercerized cotton cellulose (*I*) shows no marked changes in degree of swelling, heat of sorption, sorption of dyes, or relative wet strength. Pulp (*II*) (origin not given) also shows no appreciable differences within the D.P. range of 1050 and

475. Mercerized cotton (*III*) shows a marked increase in wet and dry strength over *I*. As indicated by the heat of sorption and dye retention, both *I* and *II* show a great increase in inner surface after treatment with alkali, but repeated mercerization of *I* did not augment this effect. On drying *III*, the degree of swelling decreases to approximately that of *I*. With *II*, alkaline treatment increased the heat of sorption, degree of swelling (unless the sample was subsequently dried), and sorption of dyes. When moist *I* and *III* were cooled to −150°, the relative wet and dry strengths remained virtually unchanged. With frozen *I*, however, the degree of swelling increased from an initial 46.3% to 62.6%. On the other hand, frozen *III* showed no significant changes in swelling capacity. With frozen *I*, elongation when wet increased by about 50%. There was also a slight increase in wet elongation with frozen *III*. Staple fiber (*IV*), after freezing, showed a decrease both in dry and wet strength, whereas wet and dry elongation increased. The degree of swelling decreased by about 10%. *IV* that had been treated with HCHO, when frozen, also showed a marked decrease in wet and dry strength and an increase in wet and dry elongation, but the degree of swelling increased by about 40%. Adsorption of organic vapors by cotton and viscose is also discussed together with the effect of such sorption on tensile strength. On the basis of these various data, the structure of cellulose fibers is discussed.

*Text. Research J. Sept. 1946*

## Vinyl Polymerization

**Mechanism of vinyl polymerization. IX. Some factors affecting copolymerization.** C. C. Price. *J. Polymer Sci.* **1**, 83–9 (Mar. 1946).

A consideration of the available data leads to the conclusion that the polarity of the double bond of the monomer is an important factor in polymerization and copolymerization. The fact that certain unpolymerizable monomers will copolymerize—i.e., maleic anhydride and olefins—is explained in this way. The influence of steric effects and radical stability is also discussed.

*Text. Research J. Sept. 1946* E. D. Klug

## Viscous Flow in High Polymers

**Processes of viscous flow in the deformation of high-polymer materials.** V. A. Kargin and G. L. Slonimskiĭ. *Akad. Nauk S.S.-S.R., Otdel. Tekh. Nauk, Inst. Mashinovedeniya, Soveshchanie po Vyazkosti Zhidkosteĭ i Kolloid. Rastvorov* (Conference on Viscosity of Liquids and Colloidal Solutions) **1**, 117–21 (1941) (through *Chem. Abstr.* **40**, 3328[4] (June 20, 1946)).

In nonequilibrium deformations, elasticity and flow depend on the time or rate factor, and consequently do not obey the laws of Hooke and of Newton valid for the stationary state. Prior to its establishment, the irreversible process of viscous flow and the reversible elastic restoration processes cannot be separated. Although this relaxation period is very short for either "truly viscous" or "truly elastic" substances, it can be very long in high polymers. On very rapid deformation, termed "limiting nonequilibrium deformation," even a viscous substance will behave like an elastic one and follow Hooke's law. In the stress relaxation of high polymers, orientation of the chains as a whole and that of its individual links do not as a rule coincide. The rate of the latter relaxation process within the chain is determined by the energy of interaction between chain links. Translation of the chains as a whole (flow), depending on the energy of interaction between chains, lags behind the inner stress relaxation process. It only appears in its pure form once the stationary state is established and only then is it permissible to speak of viscous flow. Translational motion of chains can be hindered or suppressed by chain cross-linking as in vulcanization of rubber; the mobility of chain links remaining free, deformation will result in pure elastic effects. Anisotropy of viscosity along and across the chain axis ("oriented fibers") can be of different origin; it can result either from stress relaxation or from viscous flow. The length of the relaxation process within the chain depends on the degree of interaction of its polar groups, specifically on the variability of that interaction with the mutual position of the groups. This variation is small in cellulose but can attain significant values in rubber, as is evidenced by the change of specific gravity on deformation and by the Joule heat effect. Inasmuch as viscous flow depends to a high degree on their mutual position, the motion being particularly obstructed in the case of parallel disposition of the chains, it is an error to rely on fast deformation in order to obtain best mechanical properties of a high-polymer material. This can only lead to temporary improvement of mechanical strength, at the expense of elastic properties. By way of viscous flow, permanent enhanced viscosity can be imparted to a material in a chosen direction; at the same time, inasmuch as in this case the relaxation process within the chain will appear in pure form, the elastic qualities of the material will be improved.

*Text. Research J. Sept. 1946*

## Twist in Wool Fibers

**Twist in wool.** Martin R. Freney, K. R. Deane, and J. R. Anderson. *Nature* **157**, 664 (May 1946).

Quantitative data regarding the twisting of an isolated wool fiber when exposed to varying atmospheric conditions are presented. Humidity in particular is shown to affect the twisting. The terms "free twist," "releasing twist," and "alternating twist" are defined. It is shown (1) that treatment with alcoholic potassium hydroxide, sulfuryl chloride, 1% caustic soda, and by wet chlorination reduce the "releasing twist" by approximately 50%, and (2) that wet chlorination and sulfuryl chloride treatment affect the "alternating twist" slightly, whereas caustic potash or caustic soda treatment results in

a reduction of this latter twist by one-third. The significance of these observations in felting is pointed out. R. W. Eyler

*Text. Research J. Sept. 1946*

## BLEACHING: DYEING: FINISHING

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### Peroxide Bleaching

**The history of the modern cotton bleach.** H. Baier and W. Hundt. *Melliand Textilber.* **25**, 349–51 (1944) (through *Chem. Abstr.* **40**, 4222[2] (July 20, 1946)).

Descriptive.

*Text. Research J. Sept. 1946*

### Coprantin Dyes

**Properties and structure of the Coprantin dye series.** R. Wittwer. *Melliand Textilber.* **25**, 274–6 (1944) (through *Chem. Abstr.* **40**, 4217[9] (July 20, 1946)).

The new Coprantin dyes, manufactured by Soc. anon pour l'ind. chim. à Bâle, are suitable for single-bath dyeing. The process is the same as with direct dyes, and fixation with the Cu-containing Coprantin salt follows the dyeing directly in the dye bath. Coprantin dyeings are much superior to direct dyeings in fastness to washing and to light. Dyeing procedures are given, applications of the Coprantin dyes are described, and many new grades of Coprantin dyes are listed and their properties are discussed.

*Text. Research J. Sept. 1946*

### Variations in Vat-Dyed Fabrics

**Color variations in vat-dyed cloth.** F. G. Krüger. *Melliand Textilber.* **25**, 317 (1944) (through *Chem. Abstr.* **40**, 4218[9] (July 20, 1946)).

The cause of frequent color tone deviations is the wet finishing method, particularly improper fulling and washing. Methods of eliminating such defects are discussed briefly.

*Text. Research J. Sept. 1946*

### Finishing Rayon Shirt Fabrics

**The influence of various finishing methods on the serviceability of staple-rayon shirt fabric. IV.** Erich Wagner. *Melliand Textilber.* **25**, 378–80, 396–400 (1944); cf. *C.A.* **37**, 6465[4] (through *Chem. Abstr.* **40**, 4220[9] (July 20, 1946)).

The results of many dry and wet scouring tests are recorded.

*Text. Research J. Sept. 1946*

### Fiber Structure and Finishing

**Which structural construction of textile fibers is best suitable for finishing treatments?** Haller. *Melliand Textilber.* **25**, 270–4 (1944) (through *Chem. Abstr.* **40**, 4219[1] (July 20, 1946)).

An evaluation of 20 published studies.

*Text. Research J. Sept. 1946*

### Acid Fulling

**Alkylnaphthalenesulfonic acid for acid fulling.** Gerhard Melzer. *Melliand Textilber.* **25**, 242–3 (1944) (through *Chem. Abstr.* **40**, 4221[9] (July 20, 1946)).

Data are given to show that alkylnaphthalenesulfonic acid is very helpful in fulling operations.

*Text. Research J. Sept. 1946*

### Rotproofing

**The rotproofing of textiles, particularly fishing nets.** A. v. Brandt. *Melliand Textilber.* **25**, 314–17 (1944) (through *Chem. Abstr.* **40**, 4223[1] (July 20, 1946)).

Chemical methods given in 17 references are discussed.

*Text. Research J. Sept. 1946*

### Sizing and Desizing

**Sizing and desizing.** Karl Walter. *Melliand Textilber.* **25**, 306–8 (1944) (through *Chem. Abstr.* **40**, 4222[1] (July 20, 1946)).

A discussion of (1) completely synthetic, cellulose-derivative, protein, pectin, oil-emulsion, oil-solvent, and starch- and starch-containing sizes, respectively, (2) the sizing of wool yarns, wool mixture yarns, staple rayon and staple rayon mixture yarns, cotton, and rayon, and (3) the diastatic desizing agents pancreas amylase (commercial products: Degomma, Tissoferm, and Diastonal), bacterial amylase (commercial products: Biolase and Desizing Agent B4), and malt amylase (commercial products: Diastafor and Terhyd MA).

*Text. Research J. Sept. 1946*

## FIBERS: YARNS: FABRICS: MECHANICAL PROCESSES

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### Agave Fiber

**Agave as a sugar-producing and textile plant.** Gino Ridolfi. *Riv. ital. essenze, profumi piante offic.* **25**, 144–6 (1943) (through *Chem. Abstr.* **40**, 3500[8] (June 20, 1946)).

Agave (cultivated in Italy) gives a sugar juice which shows: $d_{15}$ 1.0414–1.0429, total sugar 10.71–11.10, sucrose 7.52–8.89%. After 3–4 days it ferments and gives a liquor analogous to pulque, with d. 0.977, agavic alcohol and essential oils 8.47, mucic acid 0.15, acetic and valerianic acid trace, nontransformed sugar 0.29, gums 0.21, ash 0.76%. The use of agave as a textile plant is also discussed.

*Text. Research J. Sept. 1946*

### Alginate Rayon

**Seaweed rayon.** Arthur Johnson. *Text. J. Australia* **20**, 420 (1945) (through *Chem. Abstr.* **40**, 3268[5] (June 10, 1946)); *cf.* TEXTILE RESEARCH JOURNAL **15**, 474 (Dec. 1945).

Description of the manufacture of satisfactory alginate rayon from seaweeds.

*Text. Research J. Sept. 1946*

### Alginates

**Alginates [textile fibers].** C. J. Jones. *Fibres, Fabrics and Cordage* **13**, 62, 64–5 (1946) (through *Chem. Abstr.* **40**, 3267[8] (June 10, 1946)).

A discussion of the solubility of alginic acid, manufacture of alginic-

acid fibers, function of "carrier" yarns, various applications of alginate threads, alginate staple fiber, and all-Ca-alginate fabric.
*Text. Research J. Sept. 1946*

## Cellulose Ethers

**Cellulose ethers and their application to cellulose fibers.** Ralph T. K. Cornell, David T. Milne, and Donald S. Porter. *Rayon Text. Mo.* **27**, 318–19 (June 1946).

Data are given on the film properties of a series of hydroxyethylcellulose samples of varying molecular weight. The strength, stretch, and fold endurance decreased with decreasing molecular weight, determined viscometrically. Correlations between these values and the type of finish obtained on fabrics are indicated. A. R. Martin
*Text. Research J. Sept. 1946*

## Cementing Material of Long Fibers

**The cementitious material of long-shaped textile fibers.** E. Emiliani, V. Gianni, and G. Pelizza. *Chim. ind. agr. biol.* **19**, 308–12 (1943) (through *Chem. Abstr.* **40**, 3268[3] (June 10, 1946)).

The experiments were made on ramie, flax, hemp, broom, mulberry, jute, and sisal fibers. The determinations were: the soluble matter in 0.2% NaOH, and the insoluble matter. Pectins and polymers of galacturonic acid are soluble. Contrary to common opinion, pectins are not prevalent in the cementitious material. This material is greater when the fibers are short. The aqueous and alkaline extracts of ramie, flax, and hemp contain high quantities of methylpentoses among the hydrolysis products.
*Text. Research J. Sept. 1946*

## Fibers for Naval Cordage

**Cordage, research and use.** G. I. Dewey and W. P. Whitlock, III. *J. Am. Soc. Naval Engrs.* **58**, 39–48 (1946) (through *Chem. Abstr.* **40**, 3609[6] (June 20, 1946)).

Test results on various kinds of cordage, factors affecting the serviceability, and possible substitutions are discussed. While manila is the strongest and most durable cordage fiber, properly prepared and treated sisal can also do most of the tasks. The conditions of use, methods of use, and choice of size of line are of greater importance than fiber type. Cotton satisfactorily replaces flax in small cord. Since it is likely that Navy cordage will be stocked and used in more areas where mildew deterioration will be encountered, it would appear that mildewproofing and preservative treatment will be useful as precautionary protective measures. Such treatment even if applied in dilute concentration may extend the life of the cordage by about 25%.
*Text. Research J. Sept. 1946*

## Mexican Istle Industry

**Mexico's istle industry.** Beatrice du Frane. *Agriculture in the Americas* **6**, 71–3 (Apr. 1946).

Tula istle and Jaumave istle are produced from two named species of the amaryllis family while other kinds of istle, such as palma, are derived from several named species of the lily family. All of the istle-producing plants grow wild over a large area of arid land in Mexico, and only one variety is cultivated. Leaves of these plants are scraped by hand to remove the pulp after which the remaining fiber is dried in the sun. Jaumave fiber is 12 to 30 in. long, Tula is 8 to 14 in., and palma is 8 to 30 in. Practically all of the Tula and Jaumave istle and about 10% of the pita and palma istle imported into the United States are used in whisk brooms and various types of brushes. The remainder of the pita and palma istle is used in cordage and twine. In Mexico, istle is used also in the manufacture of bags and, mixed with latex, in insulation, cushions, and floats. Production and export of istle are controlled by a state-controlled organization.
*Text. Research J. Sept. 1946* R. B. Evans

## Moisture Regain

**The fine points of regain.** L. L. Lewis. *Rayon Text. Mo.* **27**, 305–7 (June 1946).

An elementary discussion is given of the problem of regain in textile fibers and yarns. The major factor is the relative humidity of the environment, although other factors must be taken into account. The time lag for the attainment of equilibrium by viscose rayon under ideal conditions is shown to be approximately 19 hrs. Under practical conditions, as when the yarn is packaged, much longer times are required. Rayon coned and conditioned at one temperature, and processed further at a higher temperature, will exhibit rough operation which will vanish as the cone warms up. 8 references.
*Text. Research J. Sept. 1946* A. R. Martin

## Swelling of Fibers

**Dimensional and structural changes in swollen synthetic fibers.** Bruno R. Roberts. *Rayon Text. Mo.* **27**, 243–5, 297–9 (May and June 1946).

This paper deals with the influence of swelling and heat plastification on synthetic fibers of the cellulosic and noncellulosic type. Stretching and shrinking of fibers and the behavior of fabrics made from these fibers are discussed. A few typical examples describe the more important changes occurring in swollen fiber structures. 16 references.
*Text. Research J. Sept. 1946* Author

## Fiber Swelling in Sulfuric Acid

**The swelling of textile fibers in sulfuric acid of definite concentration.** Haller. *Melliand Textilber.* **25**, 383–4 (1944) (through *Chem. Abstr.* **40**, 4219[2] (July 20, 1946)).

*Text. Research J. Sept. 1946*

## Wet Strength of Fibers

**Structure and properties of cellulose and its ethers. XXI. Causes of the lowering of strength of fibers of native and regenerated cellulose in the wet state.** Z. A. Rogovin and R. S. Neĭman. *J. Applied Chem.* (U.S.S.R.) **18**, 208–13 (1945) (English sum-

mary); cf. *C.A.* **37**, 2572[2] (through *Chem. Abstr.* **40**, 3600[6] (June 20, 1946)).

It was shown, as a result of study of native cotton filaments, mercerized cotton fibers, and viscose rayon, that the main factor in strength loss in the wet state is due to a change in the degree of polymerization and not to a structural change of the fiber. For the same state of polymerization, the loss is the same for native and artificial cellulose fibers.
*Text. Research J. Sept. 1946*

## Cotton Tire Cord

**Better tires from cotton.** Frank L. Teuton. *Mfrs. Record* **115**, No. 2, 4–9, 58 (1946) (through *Chem. Abstr.* **40**, 3637[3] (June 20, 1946)).

Cotton cord developed by the Southern Regional Research Laboratory is described. Results of tests showed that better cotton tire cords can be made by using varieties of cotton selected specifically for this purpose on the basis of their physical properties.
*Text. Research J. Sept. 1946*

## Action of Antiperspirant Creams on Fabrics

**Action of antiperspirant creams on fabrics.** Ruth R. Bien. *Proc. Sci. Sect. Toilet Goods Assoc.* **1945**, No. 4, 8–11, discussion, 11–12 (through *Chem. Abstr.* **40**, 3269[3] (June 10, 1946)).

Silk, wool, and acetate rayon are highly resistant to the action of these creams, while linen, cotton, and viscose rayon are extremely vulnerable under practical conditions. Maximum damage is caused by ironing without preliminary laundering. Ironing time and temperature are important factors. Strips of cotton percale were used for the tests. A description of the laboratory method is given. Creams containing a buffering ingredient gave satisfactory results. In the "bleeding" creams, a breakdown of the emulsion occurred, resulting in a watery exudate. The fabric damage (10–15% to 100%) depends on the extent of the separation. A weighed amount of a "bleeding" cream was applied to a 1-in. area on cotton cloth, which was then incubated. Buffering agent, sulfate, and Al were determined in the cloth outside the area to which the cream had been applied, i.e., in the part where the watery exudate had penetrated. Only $\frac{1}{3}$ the buffering agent had travelled with the water phase into this part of the cloth, but $\frac{2}{3}$ of the total sulfate was found in that area and only a trace of Al. This seemed to explain the greater fabric damage where the aqueous exudate had penetrated.
*Text. Research J. Sept. 1946*

## Chlorine Retention

**The effect of chlorine retention on rayon fabrics.** Walter Stump. *Rayon Text. Mo.* **27**, 189–90 (Apr. 1946).

Not only resins, but also cationic softeners and starch are said to retain chlorine when used on rayon fabrics that are subsequently laundered. A method is described for a semiquantitative evaluation of chlorine retention. The fabric is immersed 10 min. at 140°F in a solution prepared by adding 25 ml. of a 5% chlorine solution to a liter of water. The sample and control are washed with warm water until no test for chlorine is obtained. Tensile strips are prepared, heated at 400°F between metal platens for 30 sec., and the tensile strength is determined. The percentage loss of strength is used as a rough measure of chlorine retention. A. R. Martin
*Text. Research J. Sept. 1946*

## Deterioration of Dyed Fabrics

**Effect of weathering on dyes.** Anon. *Cotton* **110**, 72, 73 (June 1946).

A report of tests on the effect of different types of dyes on the rate of deterioration of cloth exposed to weather. Results indicate that naphthol-dyed fabrics deteriorate more rapidly than undyed bleached fabrics; that cloth dyed with sulfur, light-fast direct, and diazotized and developed type dyes has a greater resistance to deterioration than the undyed fabric; and that vat-dyed cloth is about equally or slightly more resistant to deterioration than the undyed fabric. Data and a description of the test are given. H. J. Burnham
*Text. Research J. Sept. 1946*

## Control of Dust-Borne Infection from Bedclothes

**Oil treatment of bedclothes for the control of dust-borne infection. I. Principles underlying the development and use of a satisfactory oil-in-water emulsion.** Theodore T. Puck, O. H. Robertson, Henry Wise, Clayton G. Loosli, and Henry M. Lemon. *Am. J. Hyg.* **43**, 91–104 (1946) (through *Chem. Abstr.* **40**, 3281[2] (June 10, 1946)).

The application of emulsified mineral oil (1–3% on the fabric dry weight) reduces the dispersion of dust and of bacteria from bedclothes by more than 90%. Water-soluble polyvinyl alcohol, esters, ethers of polyethylene glycols, etc., are much less effective. Suitable emulsions are: (1) mineral oil 88, oleic acid 8.9, triethanolamine 3.9, lecithin (antioxidant) 0.01%; (2) mineral oil 87, Triton NE 13% (T-13). Of these (1) yields the finest emulsion but tends to turn rancid and to separate on storage. T-13 is not as fine but is free from these objections. Emulsions made with other emulsifiers (K or Na soaps, dioctyl Na sulfosuccinate, Ninol, Dreft, Tergitol, propylene glycol or glycerol monooleate or monostearate, gelatin, quaternary ammonium compounds) are not as satisfactory. **II. The use of Triton oil emulsion (T-13) as a routine laundry procedure.** Clayton G. Loosli, Henry Wise, Henry M. Lemon, Theodore T. Puck, and O. H. Robertson. *Ibid.* 105–19. Details are given of the properties and application of this emulsion to cotton and woolen fabrics. Variations of pH, temperature, and of concentration (within limits) do not affect results appreciably.
*Text. Research J. Sept. 1946*

## Dielectric Heating

**Dielectric heating analyzed for textile applications.** Ralph A. Rusca.

*Textile World* **96**, 118–21, 212, 217, 220, 230 (May 1946).

A detailed discussion of the present and future applications of high-frequency heating to textiles, giving the basic theory briefly, formulas for determining power needed to evaporate water, limits of the use of dielectric heating, common industrial applications, research work done by the Southern Research Laboratory's Cotton Processing Division, and costs. Investment costs are high and for this reason the electronic process is not expected to compete with other drying methods except in specialized applications. It is said that a 10-kw. unit will evaporate 25 lbs. of water per hr. at a cost of 1.6¢ per lb. 23 references. H. J. Burnham

*Text. Research J. Sept. 1946*

## Mascarenhas Loom

**Electropneumatic loom is developed in Brazil.** Harold E. Reed. *Textile World* **96**, 129, 131, 202, 204 (May 1946).

A description of a new loom developed by Eneas G. Mascarenhas of Brazil covered by U.S. Patent 2,377,800 and B.P. 555,860 which is said to run with substantially less than the usual loom vibration thus permitting much lighter frame construction and smoother operation. Compressed-air cylinders controlled through electromagnets and relays, which in turn control the valve action, provide motion power for all parts including shedding, picking, and beating-up motions. A semi-rotary or rocking means of beating up the filling is used. A 1/5-h.p. compressor is said to be sufficient for operation at speeds comparable with customary mill practice. It is believed that the cost of such a loom will be below that of conventional equipment. A company is reported to have been formed in Brazil for manufacture of these looms. H. J. Burnham

*Text. Research J. Sept. 1946*

## Drawing Rayon Staple

**The drawing of rayon staple fiber on a pilot plant basis.** Bill McComb. *Rayon Text. Mo.* **27**, 295–6 (June 1946).

Detailed suggestions are offered for the selection, installation, and operation of drawing frames in a yarn pilot plant. Four causes are given for the appearance of static at the drawing frame: friction between stock and guides, interfiber friction during drafting, friction between fiber and trumpet and calender roll, and friction between sliver and tube gear and sides of cam during coiling. Remedies offered are conditioned atmosphere (70°F and 50–55% R.H.), static eliminator with one branch over feed section and one over delivery section of frame, and elimination of the coiler.

*Text. Research J. Sept. 1946* A. R. Martin

## Washing Staple Rayon

**The large-scale washing of staple rayon.** A. Richter. *Melliand Textilber.* **25**, 372–6 (1944) (through *Chem. Abstr.* **40**, 4222[6] (July 20, 1946)).

Descriptive. The chemical effect of washing baths on staple rayon is relatively small and is far below that of mechanical treatments.

*Text. Research J. Sept. 1946*

## Carding Rayon-Wool Blends

**Carding rayon-wool blends.** Bill McComb. *Rayon Text. Mo.* **27**, 247–8 (May 1946).

A roller top card equipped with a fancy is recommended for use in a yarn pilot plant. Practical suggestions are given for its care and operation. A. R. Martin

*Text. Research J. Sept. 1946*

## Pilot Plant for Spinning Blends

**Planning a pilot plant for spinning blended yarns.** Bill McComb. *Rayon Text. Mo.* **27**, 133–5 (Mar. 1946).

It is estimated that an adequate pilot plant should contain at least 1,000 spindles together with the appropriate preparatory machinery. The estimated machinery cost is $60,000. A well-equipped and competently staffed laboratory is requisite. Among the necessary machines is a rayon staple fiber opener and picker. Pickers, now on the market, are criticized as being far from ideal for use with rayon staple, although they can be said to do a satisfactory job. A. R. Martin

*Text. Research J. Sept. 1946*

## Cotton Slasher

**Slasher production improved by use of gas burner.** J. Larnar Moore. *Cotton* **110**, 101–3 (Feb. 1946).

A description of the installation of an open-flame gas burner between the size box and cylinders on a cotton slasher at Pacific Mills, Columbia, S. C., to pre-dry the yarn thus allowing an increase in slasher speed with the same drying capacity of the cylinders. City gas is used and a fan mixes it with filtered air and forces it into the burner. A temperature of approximately 2,600°F is maintained at the bottom of the burner. The center of the flame is about 1 ft. from the yarn. Automatic controls cut the burner off and on as the slasher is stopped and started. An increase in slasher speed of 18% is claimed. H. J. Burnham

*Text. Research J. Sept. 1946*

# MISCELLANEOUS

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## New Cotton Uses

**Many new and expanded uses of cotton and fabrics.** Anon. *Am. Wool and Cotton Reptr.* **40**, 29, 31, 33 (May 16, 1946).

New potential markets for cotton products are discussed, among which are plastic and cotton laminates for prefabricated building material. Experimental work on this material has been going on at the National Cotton Council laboratories in Texas for 2 yrs. A flameproof cotton insulation is said to have excellent possibilities, being superior in insulating value, fire-resistant, lightweight, and resistant to packing. Several other new uses for cotton

are described such as bonded webs for disposable items, and fabrics with special finishes.

H. J. Burnham

*Text. Research J. Sept. 1946*

## Plastics Survey

**Silicones—miracle of molecule engineering.** Charles A. Scarlott. *Plastics and Resins* **5**, No. 2, 7–12, 31–4 (1946); *cf. C.A.* **40**, 493[6] (through *Chem. Abstr.* **40**, 3296[5] (June 10, 1946)).

A discussion of the properties and applications of silicone resins, liquids, and rubber, and of silicone chemistry.

*Text. Research J. Sept. 1946*

## Proteins as Raw Materials

**Proteins as industrial raw materials.** A. K. Smith. *Chemical Industries* **58**, 974–7 (June 1946).

Proteins, with their complicated chemistry, have been slow to develop into industrial usefulness, but the past decade has shown accelerated progress. The protein-supply picture has changed from one of scarcity to one of plenty. Uses have expanded from the time-honored glues, gelatines, and paper coatings, into such promising fields as plastics, synthetic fibers, paints, and even fire extinguishers and insecticides. 13 references.

*Text. Research J. Sept. 1946* Author

## Sizing Spun Rayon

**An outline on warp sizing of spun rayon.** Ralph Hart. *Rayon Text. Mo.* **27**, 192–5 (Apr. 1946).

The results of the Textile Research Institute's report on warp sizing are presented in outline form. Data are also included from other sources.

*Text. Research J. Sept. 1946* A. R. Martin

## Amioca Starch

**Random review of textile progress.** T. V. Punnoose. *Indian Text. J.* **55**, 929–30 (Sept. 1945).

A discussion of Ardil, nylon, and of sizing, finishing, and printing with amioca starch. R. K. Worner

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## Documentation

**Documentary reproduction.** Lucia Moholy. *Nature* **157**, 38–40 (Jan. 12, 1946) (through *Bull. Inst. Paper Chem.* **16**, 388 (May 1946)).

The author outlines the potentialities of microfilm reproduction, including new categories of uses, as well as a number of problems involved which can be solved and organized only by coordinated effort of Government departments, libraries, bibliographical societies, information services, archives and records offices, library schools, learned institutions and scientific societies, photographic societies, publishers of books, and authors, etc. Some of these problems are the question of copyright, payment for microfilm services, exchange of experiences, the organization of effective international cooperation, etc. A few suggestions are given as a first contribution to further discussion, including the setting up of permanent offices in different countries and their coordination through a permanent universal office. Under the heading "Documentary Reproduction" in the editorial section of this issue (pp. 29–30), reference is made to the inherent drawbacks of microfilming technique which should be seriously considered before discussing any large schemes for its utilization and further development. It is also suggested that no new organizations should be created where existing ones would serve the same purpose.

*Text. Research J. Sept. 1946*

## Russian Chemical Nomenclature

**Chemical Russian, self-taught. III. Russian inorganic chemical nomenclature.** James W. Perry. *J. Chem. Education* **23**, 116–22 (Mar. 1946); cf. *B.I.P.C.* **16**, 304 (through *Bull. Inst. Paper Chem.* **16**, 412 (May 1946)).

The Russian inorganic chemical nomenclature is reviewed with particular attention to certain peculiarities which may prove troublesome to English-speaking chemists. The Russian nomenclature of the more common, relatively simple, inorganic compounds is emphasized. Russian authors of chemical papers do not hesitate to use formulas for more unusual, highly complicated compounds, thus obviating the nomenclature problem in such cases.

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## Mill Laboratories

**Laboratory control improves mill operation.** Horace L. Pratt. *Textile World* **96**, 133, 135, 137, 139, 204, 206, 208, 212 (May 1946).

Detailed description of mill laboratory functions, equipment, and personnel, as well as the various types of testing for mill control work. H. J. Burnham

*Text. Research J. Sept. 1946*

# WAR RESEARCH ON TEXTILES*

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# U. S. Research

## Statistical Control†

**Determination of statistical control and related factors in the performance of breaking-strength testing of fabrics.** Norman B. Edelman. PB 23129, n.d.; 12 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 58 (July 5, 1946)).

The present paper is based on a study conducted at the Philadelphia Quartermaster Depot designed to illustrate statistical control in breaking-strength testing of textile fabrics performed in accordance with Federal Specification CCC-T-191a. The survey was intended to demonstrate whether: (1) any person having had some experience in performing "breaks" should be permitted to perform these tests when occasion arises or whether performance of tensile strength tests is a

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* Copies of the original reports abstracted in this section may be obtained from the U. S. Department of Commerce, Office of Technical Services, Washington 25, D.C.

† This report appeared in the June, 1946, TEXTILE RESEARCH JOURNAL, page 268.—*Editor*

highly specialized technique for which only a select group is eligible; (2) there is justification in the belief that "jaw breaks" are invalid and should be deleted from evaluations of the strength of a fabric; (3) the number of "jaw breaks" obtained can be used to evaluate the skill of an operator; (4) the kind of breaks, i.e., excellent, good, or fair, as defined in the report, is related to the skill of the operator. Procedures and findings of tests are described. It was found that: (1) those subjects whose tensile testing was out of control had not met both the criteria of considerable experience and continual performance in textile testing; (2) jaw breaks which constitute about $\frac{1}{3}$ of all the breaks performed are shown to give more variable strengths and definitely lower average strengths than acceptable breaks, indicating that the jaws of the test machine contribute a weakening effect on the fabric and that jaw pressures should be known and regulated; good operators get practically the same number of jaw breaks as those out of control. Tables of data and statistical control charts are included.

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## Tentage Weathering Effects

**Temperature and humidity conditions encountered in exposure of tents.** (QM Textile Series, Report 16; QM Tent Res. Report 2.) David H. Miller. PB 27731, 1945; 49 pp.; microfilm, $1.00—photostat, $4.00 (through *Bib. Sci. and Ind. Reports* **2**, 308 (July 26, 1946)).

More than in any other type of textile usage, fabrics used in tents are subject to the destructive elements of weather. The effects of weather predominate over all other causes in the failure of tentage material. The Quartermaster Board at Camp Lee, Va., made 3 types of observations which are analyzed and discussed in this report: (1) observations in the open air; (2) observations inside the tents; and (3) temperature in the fabrics themselves. A total of 1,350 primary observations were made daily, including measurements taken from automatic recording graphs. Wind, rain, temperatures, and humidity were measured. Results are presented in graphs and tables, and photographs accompany the report.

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## Cold-Wet-Weather Clothing

**Development of special cold-wet-weather clothing: Mittens, suit, and boots.** U. S. Navy Department. Naval Clothing Depot, Brooklyn. PB 20076, Apr. 1946; 42 pp.; microfilm, 50¢—photostat, $3.00 (through *Bib. Sci. and Ind. Reports* 1, 1431 (June 14, 1946)).

The cold-wet-weather clothing described was designed for the protection of submarine personnel assigned to the bridge. It provides comfort at extremely low temperatures and may be adapted to similar uses on other craft, particularly small open boats. About 20 min. is required to dress with regular-issue winter clothing whereas about 30 secs. is required for the cold-wet-weather suit. Quilted glass-fiber batting is employed in these items of clothing as the insulating medium. Details of laboratory cold tests and field trials on the suit, boots, and mittens as a unit are given, as are analyses and physical and mechanical tests on constituent materials. Sketches and weights of various cold-weather items are included.

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## Thermal Insulation Properties

**Thermal transmission of fabrics: Review of pertinent literature.** (QM Corps Climatic Res. Lab. Report 45–89–A.) William L. Goddard and Marvin Van Dilla. PB 20548, Jan. 1946; 8 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 59 (July 5, 1946)).

Several factors influence the thermal insultation properties of fabrics. Most important is fabric thickness. Other factors include mean density, yarn characteristics and weave, fiber alignment, method of application to the body to be insulated, ambient air movement and presence of liquid water within the fabric. The apparatus used for measuring the thermal transmission of textiles usually incorporated the guard ring principle in both cylinders and flat plates. Results were expressed in various arbitrary units which are not readily compared to the present widely used *clo* unit. Furthermore, the description of the fabrics tested was usually unsatisfactory so that the results cannot be compared with exactness. In many instances the method of accounting for the air film resistance was not apparent. A chronological summary of the results of the work of the past 15 yrs., during which most of the research pertinent to textiles and clothing was done, is presented in Appendix I with footnote references to the literature on this problem.

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# German Research

## Amphibious Suit

**Letter report, suit, one-piece, amphibious w/inflation chamber, German, EB Reg. No. 2953.** U. S. War Department, Engineer Board. O.P.B. Report PB 13470, 1945; 4 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 905 (May 3, 1946)).

German rubberized one-piece amphibious suit with inflation chamber is made of heavy, reddish-colored duck, coated on the inside. Sewn seams are covered with tape on the inside and cement on the outside. The upper part is single-ply with a large-capacity, mouth-inflated air chamber that extends around the suit. It has a draw-string opening at the neck and flat gum sleeve opening. It weighs 13 lbs. and when the air chamber is inflated, it hugs the body. It is comparable to the U. S. amphibious exposure, one-piece suit, which weighs only 5 lbs., is easier to put on, and is more watertight. 3 views of the German suit and 3 of the U. S. suit are given.

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## Wash-Fast Embossing

**Producing durable embossing on rayons and a machine for coloring embossed fabrics (with coloring formulas by I. G. Farbenindustrie).** (FIAT Final Report 557.) Glenn D. Jackson, Jr. O.P.B. Report PB 13758, 1945; 7 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 963 (May 3, 1946)).

At the laboratories of I. G. Farbenindustrie at Höchst, Germany, a method of producing wash-fast embossings on spun-rayon fabrics was observed by the textile dyeing team. Urea formaldehyde and melamine resins as well as formaldehyde can be applied to a spun-rayon fabric; the fabric is embossed and cured, and a durable embossing results which will withstand washing. A machine was designed and was in production for coloring the low areas of embossed fabrics, which effect was obtained by applying the color to the relief areas of one of the embossing calendar rolls immediately before the roller turned against the cloth being embossed. To this machine was added another slide-printing device which would rub color on the high points of the embossed fabrics.

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## German Documents

**Wartime textile research and education in Germany. A survey of documents.** (FIAT Final Report 543.) Julian F. Smith. O.P.B. Report PB 3893, 1945; 25 pp.; microfilm, 50¢—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **1**, 965 (May 3, 1945)).

This report covers a survey made under instructions to seek all available significant documents, published or unpublished, relating to Germany's progress in textile science and technology during the war. It consists mainly of a list of 158 items of which photocopies or the documents themselves were collected or which were available in the I. G. Farben library, Höchst. These are arranged according to subject matter, as follows: general textile research and technology; textile topics, including cellulose, animal, and synthetic fibers, processes and machines, and textile products; testing and standardization; textile education; and lists. Section V of the report is a study of the situation with respect to textile periodicals in Germany, France, and Italy during the war and lists the 4 of any consequence left in Germany, with the table of contents of one. Section I reviews the general situation, noting that research and technology follow 6 major lines: (1) adaptation of rayon (cotton and wool types) to purposes formerly served by other fibers; (2) cottonizing bast fibers, known as "Flockenbast"; (3) adapting paper to textile uses; (4) use of special fibers obtainable in controlled areas; (5) synthetic fibers; and special finishes for prolonging fabric life or improving performance. Sections II–IV cover textile topics, testing and standardization, and textile education, giving significant statements as reported by the German experts interviewed, and referring to other FIAT reports written concerning the more important topics.

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## German Textile Printing

**The textile printing industry in Germany.** Elliot Broadbent. O.P.B. Report PB 13556, 1946; 6 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 961 (May 3, 1946)).

Limited information in this field was available because after traveling 2,500 mi. through Germany the writer saw only 4 printing machines in operation, and these were printing very coarse mixtures of spun rayon and flockenbast. However, in the printing laboratories of the I. G. laboratories at Höchst, there were samples of all the different types of work printed not only in Germany but in all Europe, and the formulas and methods used were on record there. The Germans do some excellent block work, and this is particularly true on synthetics. A very extensive use of azoics is made for this purpose. Resists under indigosols and vats are used on synthetic dress goods to a fairly large extent. Color-shop practices are usually very good. In most plants the dye is stirred into the paste by means of mechanical stirrers. The resulting paste is then passed through a vacuum strainer which has a capacity of about 25 gals. in 5 min. 90% of the indigosols used in the German printing industry are applied by the nitrite process. In addition to the nitrite used in making up the paste, more nitrite is added to the first box of the open soaper immediately before the acid developing box. Some of the indigosols are steamed before developing and some are given a hot-acid treatment. List of indigosols which give better results by either or both of these treatments, although referred to, is not included. The printing machines the writer saw were of good construction. One particularly interesting printing auxiliary is the Flu Tex Light, which shows up the slightest defects by the reflection of the ultraviolet light of the quartz lamp from the fluorescent salts in the paste.

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## Finishing Methods

**A German finish for spun rayon fabrics combining water-repellency, crease-resistance, and low residual shrinkage.** (FIAT Final Report 550.) Glenn D. Jackson, Jr. O.P.B. Report PB 14525, 1945; 4 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 963 (May 3, 1946)).

Although the process described in this report is in the experimental stage, it is worth noting because the Germans have first produced a thick, suedy, full hand by chemical shrinkage rather than trying to obtain the whole quality of the hand by a final resin treatment. Further study of this process is recommended.

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## Proofing Treatments

**The protection of textiles and related products from damage** by

**molds, fungi, insects, and flame.** (QM Textile Series Report 4.) M. L. Crossley. O.P.B. Report PB 22338, Mar. 1946; 23 pp.; microfilm, 50¢—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* 1, 1139 (May 24, 1946)).

The object of the work covered by this report was to ascertain what was done in Germany to protect textiles, textile products, and related materials from the destructive action of molds, fungi, insects, and flame; also to report any new information about useful insecticides. Phenols and their chloro- and nitro-derivatives are the chief means of protecting textiles and related products. No means have yet been demonstrated to mildewproof textiles permanently. Eulan NK, made by condensing triphenyl phosphine with 3,4-dichlorobenzyl chloride, may prove to be capable of giving the desired results. It, and related compounds, should be further studied as mildewproofing agents. The Preventols are suitable for preventing growth of molds in printing and finishing pastes but do not give textiles a protection which is resistant to rain and washing. The action of dinitrophenols in preserving wood appears to be enhanced by the presence of chromium, arsenic, and fluorine compounds. Basilit U. A. is such a mixture, and is said to give good protection against "dry rot." The Eulans seem to be the complete answer to the question of mothproofing wool, furs, and related products. Eulan is taken up readily by the wool from a neutral bath and can be applied easily to the finished goods at any time, without affecting their wearing properties or color. The Eulans have affinity for animal fibers and behave in some respects like acid dyes. They are fast to washing and light. Eulan NK gives protection against other insects, such as carpet beetles, which destroy animal fibers, and protects cellulosic materials against termites. The phosphates give good flameproofing but no way was found to prevent their washing or leaching out. Sulfamide was substituted when phosphates were not available in Germany but the best results were still far from satisfactory. Bladan, a phosphorous organic compound, seems to be a useful insecticide for spraying vineyards, and is said to be effective against the red spider. "Lauseto New," a mixture of $C_6H_5SO_2CH_2Cl$ and $p$-$ClC_6H_4SO_2$-$CH_2Cl$, behaves like DDT but is more effective against certain insects. Tetranitrocarbazole is the active component of the insecticide manufactured at Höchst under the name "Niroson," for use in place of lead arsenate. 1,8-dichloro-3,6-dinitrocarbazole, also reported to be an effective insecticide, is being developed at the Ludwigshafen plant. The processes for the manufacture of the Eulans, tetranitrocarbazole, and tetranitrobarbazole paste are given in appendixes to the report.

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## Rayon Piece Goods

**Manufacturing of rayon piece goods, Vereinigte Seidenwebereien, A. G., Krefeld.** (FIAT Final Report 662.) Ernest C. Geier. O.P.B. Report PB 8272, 1945; 3 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* 1, 961 (May 3, 1946)).

This firm, usually referred to as "Verseidag," is the largest producer in its field. It is the result of a merger of many smaller concerns in the weaving and finishing fields, and therefore is completely integrated from yarn to finished fabrics, including printing. It was in this plant that the equipment was found for printing the German aviators' night reading maps. Day reading maps were also produced. Products, machinery and equipment, and procedures are briefly described.

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## Rayon Throwing

**Rayon throwing at KUAG (Kunstseiden Fabrik, A. G.), Waldniehl near München-Gladbach.** (FIAT Final Report 658.) Ernest C. Geier. O.P.B. Report PB 8269, 1945; 2 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* 1, 962 (May 3, 1946)).

This plant is a subsidiary of the Kunstseiden Fabrik, A. G., in Elberfeld (Wuppertal). It is exclusively a throwing plant, specializing in throwing and doubling of rayon yarns, mostly viscose. Of special interest are the up-twisters winding the yarn upon a cone and a special hollow spindle up-twister converted into a combination up-twister and doubling machine.

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## Wool Pulling

**Pulling wool by the use of enzymes.** (FIAT Final Report 545.) Henry D. Grimes. O.P.B. Report PB 14526, 1945; 4 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* 1, 962 (May 3, 1946)).

Wool can be removed from pelts without detriment to the wool fibers or to the hides by the use of an enzymatic product called Arazym NSL. This process of pulling wool from sheepskins was developed by the Röhm and Haas Company of Darmstadt, who are the manufacturers of Arazym NSL.

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## Wool Scouring

**Wool scouring, wool-grease recovery, and other by-product recovery in Germany.** (FIAT Final Report 546.) Henry D. Grimes. O.P.B. Report PB 13757, 1945; 12 pp.; microfilm. 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* 1, 962 (May 3, 1946)).

During the war, synthetic alternatives were used for scouring to take the place of soap, which was not available. The general mechanics of the scouring process agree essentially with U. S. practices except that the wool is given a rinse in water only, before the usual scour with soap. This is done to recover the water-soluble potash salts. The recovery of wool grease is mandatory to prevent pollution of streams, the cost of recovery exceeding its selling price.

*Text. Research J. Sept. 1946*

# MOTHPROOFING OF WOOLEN MATERIALS IN EUROPE

The entire life cycle of the clothes moth from the egg to the adult moth is described and illustrated with photomicrographs, many of them in color. The progress of fibrous material through the digestive tract of the moth larva and the effect of mothproofing treatments are shown.

Included in this report by a team of investigators is a report describing the status of mothproofing in England and on the continent by Werner von Bergen, also a report by M. L. Crossley which gives the chemical composition and methods of application of Eulan, a permanent type of mothproofing compound developed by the Germans. A comprehensive bibliography covering the field is an important feature.

This report will be of wide interest not only to the manufacturers of woolen materials but to the distributors of merchandise and to those engaged in the treatment of fabrics, such as laundries and cleaning establishments.

**Price $1.50 per copy**

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# SYNTHETIC FIBER DEVELOPMENTS IN GERMANY

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